Debunking the Myth of SBR Dangers

Tire Crumb Rubber Use in Artificial Turf Fields: The Latest in a Long List of Scare Tactics

Section 1:
Intro Doc

INTRODUCTION

The success of artificial turf fields has had an impact not only on our competition, but also on the suppliers of natural grass. Artificial turf has also had an impact on the local communities where the fields are installed.

The installation of any new artificial field is usually followed by lights, increased usage during the day and night and by the crowds that such activity brings. Concessions, traffic and other inconveniences have affected the homeowners nearby.

The local community usually feels threatened by any new construction and unless the homeowners have children who use the facilities, their reaction is usually based on protecting the peace and quiet of their lives and the value of their property.

In past they have been unable to stop progress. But now the natural grass industry and our competitors are using the local residents to put forward their own agenda to try to stop the installation of FieldTurf fields.

There is nothing like an environmental or health scare to put the brakes on new construction. And we believe it is the natural grass industry lobby and our other all rubber competitors that have been feeding local communities, their town halls and the local media with these phony scare tactics. And it's working.

We have to be diligent in providing accurate information to make sure everyone understands the truth.

First it was silicosis - threats that playing on artificial turf with sand meant inhaling silica which cause silicosis. This proved to be a ridiculous assumption, since the size of our smallest particle of silica sand is many times larger than the particle size the lung is able to ingest. In any case, it required testing to prove that it was in fact an empty threat.

Then it was heat. The dangers of kids dying on hot artificial grass fields was fuelled by a few tragic incidents - which actually took place on natural grass, not on artificial turf. Today, that threat still raises its head occasionally.

Next followed the staph scare, where artificial turf was blamed for serious infections that were making headlines. As it turned out, this was a completely false statement as no FieldTurf field has been found to contain any infections - which it turned out were usually caused by bad hygiene and surfaces inside the sports facility training and locker rooms.

And now the latest scare is the dangers of cancer causing materials found in the SBR crumb rubber from used tires. This has caused a big scare in Europe but has been proven to be as false as the rest of these scares. The scare starts with PAHs or Polynuclear Aromatic Hydrocarbons.

In the making of salt, two dangerous particles Sodium and Chlorine are combined to create salt, a harmless substance consumed daily by every human. The manufacture of rubber tires also combines some dangerous particles during the vulcanization process. While such substances are being phased out of production worldwide, these dangerous substances cannot be extracted from the tire product, unless extreme solvents and processes are utilized.

If a child was to eat a handful of crumb rubber, the particles, which may contain dangerous materials, will pass right through the body untouched. The human digestive system is unable to break down these compounds. In the same way, the rubber cannot be absorbed by the lungs or the skin and therefore, like salt, potentially dangerous substances have no effect on human safety.

The following pages are copies of existing letters, documents and studies that debunk this myth.

CONSIDER THE MATH

To date 46,000,000,000 (46 billion) tires have been worn out on our roads. During this same period 160,000,000 (160 million) tires have been ground up and put into 4,000 playing fields.

If we are to believe the scare tactics that tire rubber particles represent a health hazard, consider this:
The large rubber granules in playing fields represent less than .03% of the rubber particles vehicle wear has ground into fine airborne particles, currently part of our global atmosphere.

To calculate the potential danger posed to children playing on an infilled field, each field would represent 1/4000 of a total field hazard of .03% which is equal to .0000075.

Section 2:

FIFA

An Open Letter Concerning the Potential Cancer Risk from Certain Granulate Infills from Artificial Turf

cc: J. Champagne, Dr. J. Ekstrand, M. Harvey, Dr. C. Fuller, M. Timmer,
Dr. E.G Harrison, L. Bretscher, N. Fletcher

Zurich, 12 July 2006

An Open Letter concerning the potential cancer risk from certain granulate infills from artificial turf

As you will be aware both FIFA and UEFA have invested substantial resources in recent years in the development of artificial turf to ensure more people, more often have more opportunities to participate in Football at all levels of the game in a safe environment.

Both organisations have both been aware of recent reports that have suggested a potential cancer risk from certain granulate infills from artificial turf.

FIFA and UEFA have investigated this issue and analysed the risk involved. In particular we have reviewed the results of numerous studies into this issue and our findings to date are listed below:

- The list of publications which FIFA and UEFA have scrutinised is given below.

- The studies to date have concluded that "PAHs [Polynuclear Aromatic Hydrocarbons] are not released or at most negligibly released from tyre abradate" (The University of Dortmund Institute for Environmental Research 1997). Epidemiological studies conducted by the Health Effects Institute, The World Health Organisation and other investigators do not implicate tyre wear particles in ambient air as contributing to human health effects (respiratory and cardiovascular diseases)

- In general tyre abradate is a much finer particulate than the granules used as infill materials in Football Turf. The research demonstrates that the finer the particles the greater the surface area and higher potential for chemicals to leach out of the rubber.

- The majority of the studies have been on higher surface area particles and have concluded they are currently acceptable. Therefore the larger granules used in artificial turf will have even less potential for emissions. For example a study undertaken by the Danish Ministry of the Environment

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concluded that the health risk on children's playgrounds that contained both worn tyres and granulate rubber was insignificant.

The available body of research does not substantiate the assumption that cancer resulting from exposure to SBR granulate infills in artificial turf could potentially occur. For further information of the issue and the risk, please consult the references below.

Prof. Dr. Jiri Dvorak
FIFA

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Section 3:

SAPCA

The Use of Recycled Rubber in Sports Surfaces

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The Use of Recycled Rubber in Sports Surfaces

In conjunction with the British Standards Institute (BSI), the Sports and Play Construction Association (SAPCA) is helping to prepare new European (CEN) Standards for artificial sports surfaces. Through this work SAPCA has become aware of concerns being voiced in some European countries over the use of recycled rubber from vehicle tyres in sports surfaces. In response SAPCA has convened a working group of UK experts to investigate the situation. So far, SAPCA has carried out a substantial review of previous national and international studies undertaken by scientists on the risks from rubber aggregates in sporting contexts.

Waste rubber aggregate materials, derived primarily from vehicle tyres, are currently widely used in roads, railways, building construction, agriculture, packaging, bulk products, mining, automobiles and trucks, marine structures, landscaping and sports and play surfaces. The issue originates from some of the materials used in the manufacture of rubber. There are a number of organic and inorganic substances used in rubber manufacture that are potentially hazardous inviting caution. It has been suggested that there may be risks from leaching and therefore chemical pollution of soils and waters; there may also be possibilities of inhalation of volatile constituents, skin contact, ingestion, and abrasion of surfaces with particulate release.

SAPCA's opinion is that, because tyre rubber is designed to be strong, durable and substantially impermeable, it is unlikely that any losses could occur to air or water in concentrations that would pose serious human or environmental risk. This opinion is supported by the reports and academic studies reviewed, which have shown insignificant environmental effects of such chemicals or release of volatiles and particulates into the atmosphere. SAPCA is continuing with its investigations but subject to that our view is that there are negligible additional risks to humans based on theoretical extrapolation - indeed we have not identified from our initial investigation any evidence of reported symptoms or adverse health effects.

As with any health, safety or environmental concern, SAPCA will continue to maintain a watching brief on the situation. SAPCA has therefore initiated a dialogue with independent researchers and experts in this field. Where any avenues of further research are identified the Association will actively support necessary programmes to ensure that these materials continue to be used safely and meet the required standards for all concerned.

THE USE OF RECYCLED RUBBER IN SPORTS SURFACES

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From SAPCA's perspective, it is reasonable to suppose that, because tyre rubber is designed to be strong, durable and substantially impermeable, it is unlikely that any losses could occur to air or water in concentrations that would pose serious human or environmental risk. This opinion is supported by the reports and academic studies reviewed, which have shown insignificant environmental effects of such chemicals or release of volatiles and particulates into the atmosphere. SAPCA is continuing with its investigations but subject to that our view is that there are negligible additional risks to humans based on theoretical extrapolation - indeed we have not identified from our initial investigation any evidence of reported symptoms or adverse health effects.

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FIFA, the international governing body for football, has also commented on the reported concerns. For a copy of FIFA's open letter, dated 12 July 2006, please click [here].

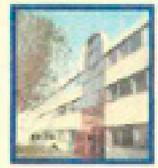
Section 4:

Laboratory of Research & Control for Rubber & Plastics

Environmental Impact End of Life Tire Crumb Rubber

LRCCP

Laboratoire de Recherches et de Contrôle du Caoutchouc et des Plastiques



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2 rue de l'Égalité
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Att. Mrs Boucher

Documentary report D

N°D321394/EN
15/05/2006

Use of end-of-life tyre rubber crumb in sports floors: environmental consequences. 2006 update

Centre Français du Caoutchouc et des Polymères industriels

http://www.lrccp.com/
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N° SIRET : 78540237100021 – APE : 731Z – ÉTABLISSEMENT PROFESSIONNEL À BUT NON LUCRATIF - LOI DU 17 NOVEMBRE 1943

Documentary report D
N°D321394/EN

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Use of end-of-life tyre rubber crumb in sports floors: environmental consequences. 2006 update

Author: Catherine RIGAUD

References:

LRCCP estimate no 394.06/CR dated 05/04/2006
Acceptance according to estimate dated 13/04/2006
LRCCP report D320971

It consists of **9 pages and 9 appendices.**

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I - INTRODUCTION

The purpose of the study is to update our knowledge about the environmental consequences, if any, of using rubber crumb from end-of-life tyres in floors for sports facilities and other play areas.

Our first documentary report, no D320971, dating from August 2002, clearly demonstrated the ecological safety of rubber from end-of-life tyres.

To facilitate understanding and comparison of the two documentary reports, we have retained a similar layout.

Moreover we have intentionally avoided using documents that could be thought to be too heavily loaded towards one technical opinion.

Some bodies (suppliers, rubber industry trade associations, ecological associations, etc) could be considered to be biased, and could be tempted to present arguments, either for or against, lacking in objectivity.

II – CONVENTIONAL BIBLIOGRAPHICAL DATA BASE

II.1 *Results*

The research equations were reconsidered, with the same technical descriptors, by adding a limit to the dates of the results, that is by specifying that the references of the documents cited must have been obtained from 2002 onwards.

The LRCCP data base only provided one interesting result, discussed in the next paragraph. Processing the English RAPRA specific polymer data base, produced 6 references, against 9 references from the American COMPENDEX engineering base.

After consultation of the sources, we observed that the references from the RAPRA data base referred either to recycling operators proposing new types of crumb as materials for use in sports floors, or tyre waste used in applications that could be considered to be almost traditional such as asphalt, submarine reefs, drainage materials, etc.

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II.2 *Primary documents retained* (grouped together in the "Documents" appendix volume)

a) Updated research on the **LRCCP data base** provided us with a recent reference which seemed interesting (*appendix no 1*).

It is a document from a German environmental research Institute, entitled: "Estimation of the environmental exposition for additives in the rubber industry", by M. Gräfen, K. Hesse, and W. Baumann published in the magazine, Kautschuk Gummi Kunststoffe (Vol. 54, no 12, 2001).

However, on reading the document, its content does not appear to be directly related to our subject, since it deals with effluents emitted by plants processing rubber (including all types of elastomers) in the tyre and industrial rubber fields.

b) COMPENDEX reference no 2 (*appendix no 2)*

This **document** is the **most recent** of those appearing to merit attention. It is written collaboratively by American authors, contributing from within university bodies, institutions or companies working in the field of chemical risk. It was published in "Environmental Toxicology & Chemistry", Vol. 25, no 2, **of February 2006**.

Although the use of end-of-life tyre waste is currently widely accepted in the USA (cf. ASTM standard D6270), some states were reticent as to certain engineering applications, because of the small amount of data available about possible toxic risks presented by effluents of this waste caused by washout.

The purpose of the study was to assess the toxicity of leachate from shredded material from tyres used as road fill, and the conditions to make its incidence negligible both above and below the ground water table.

In the tyre fragments placed in situation (in 1993) pieces of metal cord were exposed intentionally. A site which did **not contain any tyre waste** was used as **comparative bench mark**. Samples were collected between October 2000 and January 2002.

Chemical analyses were made according to the methods laid down by the US EPA (the main American environmental agency) to characterise the metals and the volatile and semi-volatile organic compounds.

Toxicity tests (detailed test methods) in the water processing monitoring laboratory, showed that the survival/reproduction responses of the aquatic organisms concerned **satisfied the EPA acceptability criteria. These results were confirmed by those from a toxicity reference crossover study**.

Targeted toxicity identification assessment tests were carried out with many samples, as well as blank tests. Geochemical modelling software was used to corroborate the results obtained.

The parameters with the most effect on the dispersion of the leachates are the gradient and the hydraulic conductivity, directly linked to the flow speed of the underground water and the dilution of the leachates. The infiltration action by rain water is also taken into consideration, with the ratios, transit speeds in the ground and the nature of the ground.

The results all these tests, which were very complete and detailed, show an **insignificant incidence of the presence of tyre fragments on the characteristics of washout water above the level of the ground water table.**

Below the ground water table, observable pollution is only from the metals (especially iron) from the tyre reinforcement cords.

c) COMPENDEX Reference no 4 (*appendix no3)*

Between 1999 and 2001 the Canadian authors, one of whom belongs to Winnipeg University Civil Engineering Department, studied the thermo-mechanical behaviour of shredded material from end-of-life tyres used in underfloor thermal insulation, and its potential incidence on the quality of underground water. A 45 cm gravel layer covered the shredded tyre material, laid in five successive 15 cm layers.

In this study we find the influence of the presence of end-of-life tyre fragments on the air, ground and water, with an increase in the levels of mineral compounds (aluminium, iron and manganese) due to the presence of pieces of metal reinforcement cords.

Analysis of the organic compounds shows that their levels are below the detection thresholds indicated by the test method.

d) COMPENDEX Reference no 8 (*appendix no 4)*

This study, presented by a university academic (Civil and Environmental Engineering Department) and two co-authors specialised in horticulture, considered the absorption properties of rubber particles from tyres in relation to nitrogen and phosphorous, incorporated into the intermediate drainage layer of sandy soils and golf putting green underlayers.

Comparative analyses were done on a grass derivative. **A significant reduction in the nitrate concentration in the leachates compared with a traditional gravel layer was observed**, even though the reactive mechanism remained obscure.

The presence of particles had **no negative effect on the vegetation** (growing, density, quality or colour).

III- LRCCP DOCUMENTARY RESOURCES

The **American ASTM D 6270-98 standard**, entitled "Standard practice for use of scrap tires in civil engineering applications", was **reapproved in 2004** (*appendix no 5).*

Concerning the potential toxicity of tyre waste from washout, including by acid rain water, the same **evaluation method is retained** (USEPA Method 1311; a document of which the version has not been revised since our first report).

Consequently the results of the tests carried out to date remain valid. The levels of metals and organic compounds measured, after washing of the end-of-life tyres, are considerably lower than the maximum values laid down. **Hence end-of-life tyres are still considered as waste that is not dangerous for the environment** (§ 7.4).

IV- DATA OBTAINED VIA THE INTERNET

a) A tyre recycling programme, dating from **December 2002**, emanating from "Washington State Department of Ecology", examines the various destinations for end-of-life tyres.

In the extract supplied (*appendix no 6),* this department specifies that according to the survey of other state agencies and in-depth studies, the use of shredded end-of-life tyre material as fill does not seem to have a negative influence on the composition of gasses or effluents.

Among the examples of applications illustrating the Ford Motor/RTG programme, **rubber crumb** is **incorporated into floor coverings for school play areas, horse racing tracks and football pitches.**

b) A publication (*appendix no 7)* from "Particle & Fibre Toxicology", dating from **March 2005**, was written by a team from Milan University, involving the departments of Environmental Science & Biology.

It is considered that road transport is responsible for 80 % of the inhalable particles in urban areas. Of this only 3-7 % can be blamed on tyre and brake wear.

From this study, centred mainly on inhalable substances and the potential consequences on the respiratory tracts, we can note that the size of the ultra-fine particles likely to be toxic is between 2.5 µm and 100 nm. Tyre debris, generated by tyre wear on the roads has larger particle sizes. Only a very small percentage can be classed in the category known as the inhalable fraction. We are a long way from the crumb incorporated in the floor covering, which is a much larger size than wear debris.

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However, out of the compounds dropped in eluates, zinc seems to be the one that needs to be monitored the most closely, as its level increases with a fall in the ambient pH. This influence of the acid pH was already mentioned in our first report.

c) An article published in **January 2006** in "Environmental Health Perspectives", whose authors are either university academics or health workers, relates a **very pertinent case study** (*appendix no 8)*.

It is a **risk analysis** on the use of **end-of-life tyre rubber crumb in play areas,** in comparison with the use of sand or wood shavings.

In order to examine the risks, American scientific literature was reviewed as was data returned from the childcare network. **Analysis of the combined potentialities suggests that the use of rubber crumb as covering for play areas presents a very low risk both for the children and for the environment.**

The toxicity on aquatic organisms, observed in an aqueous solution extracted from a new covering, disappears for the same test done on a 3 month old mat.

The document mentions a lack of specific work on the exact subject, but the potential allergy to latex, transmitted through the skin or the air, is irrelevant as these allergens do not "survive" the vulcanisation stage necessary for the manufacture of a tyre.

d) In this previously-mentioned article, **one study** (by D. **Birkholz**, Professor in the Faculty of Medicine and Pharmacy at the University of Alberta) is mentioned which is apparently **considered as the reference** on the subject. This led us to look for the source document.

It is a Canadian technical publication of **July 2003**, which appeared in "J. Air & Waste Manag. Assoc.", entitled: Toxicological evaluation for the hazard assessment of tire crumb for use in public playgrounds (*appendix no 9*).

Favoured for its shock and noise absorbing qualities and the suppleness it provides to playground flooring compared with sand or asphalt, crumb is examined from the point of view of possible effects on children's health (sensitivity, dermatitis, etc).

Workplace dangers existing in the manufacture of rubber goods (including tyres) do not need to be considered in this situation as the product used, crumb, is stabilised, aged, washed, and dust-free.

The possible danger for the children is from direct contact with the chemical compounds contained in the crumb, which could happen by ingestion or as a result of contact.

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A qualitative **assessment of these risks** produced the following conclusions:

- **Ingestion on the ground is unlikely** and the gastric juices of the digestive system are not powerful enough to extract the toxic products from the crumb.
- **Inhalation is considered negligible** as the crumb does not contain volatile chemical compounds under pressure.
- **Dermatological contact presents a generally very low risk.** A more effective solvent than water would be needed to extract toxic compounds in quantity, and an adequate (non polar) carrier would be necessary to penetrate the skin and cause significant absorption.

The ecological impact, if it exists, associated with the use of crumb in play area floors, depends on mechanisms for releasing chemical products into the immediate environment and the possibility of bioaccumulation.

Consequently the second, quantitative, part of the study, tried to establish whether crumb compounds, in an aqueous environment, were toxic in relation to the aquatic environment. In vitro genotoxicity tests were carried out as well as standard biological tests with representative leachates (250 g of crumb washed in 1 L of water and then filtered).

The genotoxicity results were negative: **absence of chemical compounds likely to be chromosomically noxious**.

The biological tests indicated a moderate toxic risk for aquatic species, in the case of leachates from "fairly recent" crumb. This toxic activity falls away fast naturally, probably by dilution into non toxic compounds. The maximum duration of this "toxicity" estimated at a maximum of 3 months outdoors, makes the danger of **contamination of the crumb very low**, considering the volumes of water participating in spontaneous dilution (rain, snow, underground water, etc).

IV – CONCLUSION

As in our first study in 2002, this update mainly contains data from North America.

The large volume of end-of-life tyres linked to automobile activity, continues to motivate the managers concerned strongly because of the recycling aspect.

The American ASTM D6270 standard, issued in 1998, establishing the rules of good practice in the use of tyre waste in civil engineering, was revalidated in 2004 by the commission responsible. This document makes reference to specific tests of contamination and toxicity in relation to the environment.

For tyre waste, one of the major sources of possible contamination into the ground results from the phenomenon of washout by surface run-off water.

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The main data obtained on this subject concerns the use of crumb as fill for road or other foundations.

It has been shown that this tyre waste has no toxic influence on the fauna and micro-aquatic organisms.

The only chemical elements present and potentially contaminating are metals, especially iron, from fragments of tyre reinforcing cords. We should bear in mind that these fragments are absent from rubber crumb.

More directly on the subject of sports and play area floors, the Canadian study of 2003 is the authority on the subject.

The following main points are significant:

- In the event of ingestion of crumb particles, although it is highly improbable, the particles do not present any toxicity, the digestive system is not powerful enough to extract the chemical components from the rubber.
- Inhaling is practically negligible because crumb does not give off volatile products.
- Direct contact with the skin does not present any real danger, even from the point of view of allergy.
- From the genetic point of view, biological tests have shown the absence of genotoxicity.

This data will be all the more reliable if the crumb used has been washed beforehand, to remove any easily extractible or volatile components.

This updated data confirms that the end-of-life tyre crumb is a perfectly suitable material for sports and play area floors, without any palpable danger of toxicity for users or the environment.

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Recherche et Contrôle L R C C P Caoutchouc et Plastique

Responsable du Département Information Scientifique & Industrielle

Section 5:

Air & Waste Management

Toxicological Evaluation for the Hazardous Assessment of Tire Crumb for Use in Public Playgrounds

TECHNICAL PAPER

ISSN 1047-3289 *J. Air & Waste Manage. Assoc.* 53:903–907

Toxicological Evaluation for the Hazard Assessment of Tire Crumb for Use in Public Playgrounds

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Department of Public Health Sciences, University of Alberta, Edmonton, Alberta, Canada

ABSTRACT

Disposal of used tires has been a major problem in solid waste management. New uses will have to be found to consume recycled tire products. One such proposed use is as ground cover in playgrounds. However, concern has been expressed regarding exposure of children to hazardous chemicals and the environmental impact of such chemicals. We designed a comprehensive hazard assessment to evaluate and address potential human health and environmental concerns associated with the use of tire crumb in playgrounds. Human health concerns were addressed using conventional hazard analyses, mutagenicity assays, and aquatic toxicity tests of extracted tire crumb. Hazard to children appears to be minimal. Toxicity to all aquatic organisms (bacteria, invertebrates, fish, and green algae) was observed; however, this activity disappeared with aging of the tire crumb for three months in place in the playground. We conclude that the use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment.

IMPLICATIONS

Reuse of tire crumb as playground covering is cost-effective waste management and prevents injuries in playgrounds, but its use has been limited by safety concerns. Hazard assessments associated with exposure to water-soluble chemical extracts of tire crumb suggest low risk for carcinogenicity or ecosystem impact. This is the first case where the standardized, multispecies Potential Ecotoxic Effects Probe (PEEP) index was used to determine whether a recycling industry was having an adverse effect on the environment. This may be a good model to use for assessing risk associated with other recycling industries.

INTRODUCTION

The environmental and human health risk of ground cover made from shredded tires for enhanced safety in playgrounds was investigated. Such products, if successful in the marketplace, may improve safety while providing a disposal option for recycled tires. Disposal of used tires has been a major problem in solid waste management.[1–3] Because of their elastic properties and tensile strength, tires present difficult challenges for physical disposal and reduction. Their hollow shape allows water to collect and creates a hazard caused by insect breeding. Combustion of tires at low temperatures is difficult to control and produces a variety of products that are unacceptable as emissions to air and residues, such as benzene, that may contaminate groundwater. Combustion at high temperature, which is typically conducted on a large scale in cement kilns, produces fewer emissions but has been criticized as a source of metal emissions and because of the potential to contribute to ambient air pollution.[2]

The unattractive options for disposal and destruction of used tires has resulted in an accumulation of discarded tires. Transport of used tires offsite is expensive and there is little demand for them, so they tend to accumulate in local junkyards and piles. Storage of used tires in large quantities presents a serious fire hazard. In Canada, this issue became the subject of intense media attention during and after the fire in Hagersville, Ontario, in 1990, when a stockpile of 14 million scrap tires burned uncontrolled for 17 days and forced the evacuation of 1700 residents.[4] Smaller tire fires have occurred since then,[3] but most facilities now maintain smaller piles in an effort to limit their hazard. Canadian provinces, except Ontario, now divert 70% of their scrap tires into recycling.[4]

Recycling and conversion into final product may not absorb all discarded tires that are produced, but it reduces the load and therefore the disposal problem.[5] The vulcanized rubber in tires has potentially desirable properties and a high energy content. Eventually, value-added products and markets for tire rubber may be developed that support tire recycling on a large scale. The market for recycled tires is encouraged by policies of the Canadian provincial governments but is limited by the available options for converting the recycled material into product. New uses will have to be found to consume recycled tire products.

A first step in developing such products is the conversion of the tire into a more manageable physical form. Tire crumb is shredded rubber obtained from spent vehicle tires. A search of the Internet found three companies currently engaged in the commercial production of tire crumb, in Florida, Belgium, and Portugal. (Many more firms are engaged in the manufacture of crumb rubber–modified asphalt.)

One such proposed use is as ground cover in playgrounds following shredding of the tires to produce a crumb. The advantage of using tire crumb, as opposed to sand or asphalt, in playgrounds is that its shock-absorbing properties reduce injuries to children using playground facilities.[6] However, concern has been expressed in Alberta, as elsewhere, regarding exposure of children to chemicals associated with the tire crumb product and the environmental impact associated with offsite migration of such chemicals. Available data on the safety of tire manufacturing are not germane to the question of risk associated with completed, vulcanized, aged, and shredded tires, because exposure in the tire manufacturing industry is qualitatively different.[7–9] Likewise, although the National Institute of Occupational Safety and Health has examined the safety of crumb rubber–modified asphalt paving in several health hazard evaluations, the exposures described (see, e.g., ref 8) apply to the heated and melted product in combination with asphalt. This study did not consider other possible health effects on children, such as sensitization and dermatitis. These were considered unlikely to be limiting factors in the use of tire crumb in playground surfaces.

DEFINITION OF THE PROBLEM

Recycling Activity in Alberta

Recycling has been a particular priority in the province of Alberta, Canada. Approximately 2 million tires are discarded annually in the province of Alberta, which has a population of 2.7 million. A cooperative program was developed between the Alberta Centre for Injury Control and Research and the Tire Recycling Management Association of Alberta to evaluate the environmental risk associated with the use of tire crumb on playgrounds in the province. The potential for local exposure of children from surface runoff and puddles was the major concern expressed. Likewise, it was recognized that environmental concerns may arise regarding playground runoff from rain and snowmelt contaminating surface waters after collection by storm sewers and release to the aquatic environment. The study was therefore extended in scope to include components on health hazard and environmental impact.

Human Health Hazard

Health risk assessment for vulcanized rubber products has emphasized dermatitis and anaphylaxis associated with latex gloves, an exposure situation not applicable to this case. Rubber manufacturing is associated with hazards that do not apply in this case, in which the product is finished, aged, washed, and free of dust.[4,5] The health hazard for children, if any, associated with the use of tire crumb in playgrounds depends on the presence of an intact pathway of exposure and direct contact with chemicals that may be present in tire crumb. This exposure may occur dermally (skin contact) or orally (via ingestion). Inhalation of volatile constituents is not a plausible route of exposure because no volatile compounds would be expected to remain in the shredded, solid material. Each of these exposure routes was assessed to determine the hazard associated with exposure, but ingestion represents the exposure route of greatest significance.

A qualitative exposure assessment reached the following conclusions: Oral ingestion was deemed to be low in overall hazard because ingestion of tire crumb on the ground is not likely, and the gastrointestinal tract is unlikely to be efficient in extracting toxic chemicals from tire crumb. Tire crumb does not contain chemicals with high vapor pressures; thus, exposure via inhalation was deemed inconsequential and the resulting hazard negligible. Dermal exposure was deemed to be unlikely and, therefore, to present low overall hazard. A carrier solvent more efficient than water would be needed to extract toxic chemicals from tire crumb in quantity, and a suitable nonpolar vehicle would be required to penetrate protective skin layers for significant absorption. This is implausible in a playground situation.

Cancer hazard was chosen as the outcome of greatest concern, both because the issue had been raised in the queries received and because it is one of the few biologically plausible hazards associated with low-level exposures to the chemicals most likely to be released. The objective of this part of the study was to determine whether ingestion of a small amount of tire crumb by small children poses a cancer hazard with respect to exposure of chemicals at levels likely to be encountered, as measured by relevant in vitro predictive assays.

Environmental Hazard

The environmental impact, if any, associated with the use of tire crumb in playgrounds depends on the presence of a mechanism of release into the environment of chemicals present in tire crumb that may bioaccumulate. This would probably only occur in the aquatic environment as a result of runoff or groundwater contamination. The objective of this part of the study was to determine whether waterborne constituents of tire crumb demonstrate toxicity to organisms in the aquatic environment.

METHODS

Human Health Hazard

Exhaustive extraction (Soxhlet, 16–18 hr) of 200 g of tire crumb was performed with dichloromethane, omni solvent grade, which was obtained from EM Science. SOS materials, as well as the dimethyl sulfoxide (DMSO), were obtained from Environmental Bio-Detection Products, Inc. The eluted constituents were exchanged into DMSO at final concentrations that were tested at 0.24–2.2 mg/mL of hydrocarbon in DMSO. Genotoxicity testing was then performed using the resulting extracts with and without S9 (liver homogenate) activation in the following systems: *Salmonella typhimurium* mutagenicity fluctuation assay (TA98, TA100, TA1535, and TA1537), SOS chromotest, and Mutatox. All Ames strains, as well as polychlorinated biphenyl–induced S9, were obtained from Molecular Toxicology, Inc. Extracts were tested for acute lethality using Microtox in serial dilution to identify toxicity thresholds using standard methods.[10,11] Genotoxicity was defined as a minimum 1.5-fold increase in colony count relative to solvent controls, with a dose-dependent response. Marginal toxicity was defined as an increase in colony count not exceeding 1.5-fold and no dose-dependent response. Absence of toxicity was defined as a lesser increase in colony count and no dose-dependent response.

Environmental Toxicity

Tire crumb in 250-g samples was leached in 1 L of water to produce the test leachate. The leachate was filtered to remove particulate matter. The leachate was then tested using standard methods and control exposures[12] in a battery of aquatic tests representative of the major trophic levels in the aquatic receiving environment: luminescent bacteria,[13] invertebrates,[14] fish,[15] and algae.[16] Luminescent bacteria, *Vibrio fisheri*, were employed as a test organism following the procedures of Environment Canada.[10] The microcrustacean *Daphnia magna* was used as a test organism following the procedures of Environment Canada.[14] Toxicity testing using the fathead minnow, *Pimphales promelas*, was performed using the procedures of the U.S. Environmental Protection Agency.[15] The freshwater alga *Selenastrum capricornutum* was used to test for toxicity following the procedures of Environment Canada.[16]

Quality control for all toxicity tests was maintained by using a positive control for toxicity testing reference toxicants, following the procedures of Environment Canada.[12] Lauryl sulfate was used as the reference toxicant for luminescent bacteria. Sodium chloride was the reference toxicant for the invertebrate species, fathead minnow, and green alga.

Toxicity was quantified by derived toxic units (TU). This calculated value is derived from a probit analysis to determine the estimated concentration that produces an effect in 50% of the organisms tested (EC_{50}), which may be a lethal effect (LC_{50}) or an inhibitory effect (IC_{50}). The level so derived is inverted and multiplied by 100. This value has the property of increasing with increasing toxicity and is dimensionless because it is based on serial dilutions of the leachate.

$$TU = 100/EC_{50} \tag{1}$$

If the initial testing revealed a toxic response using aquatic organisms, two further sets of tests were performed. The toxicity of leachate from fresh tire crumb was compared with that from aged tire crumb that had remained in place on a playground for three months, by the same bioassays. The leachate was also modified by the addition of sewage seed and nutrients and by aeration of the filtrate for 5 days. The persistence of toxic response over time was then determined and toxicity assessed by calculating the Potential Ecotoxic Effects Probe (PEEP) index , which is a weighted formula reflecting the consistency of toxic responses in various test systems.[14]

RESULTS

Human Health Hazard

Table 1 presents the results of in vitro genotoxicity assays. No test was clearly genotoxic. No tests performed without microsomal activation demonstrated genotoxic activity. Seven tests were marginal after activation but did not meet the criteria for genotoxicity and are considered negative.

Environmental Hazard

Table 2 presents the results of species-specific lethality assays. Bioassays of leachate obtained from four tire crumb samples revealed that all samples were toxic to all four species tested (luminescent bacteria, invertebrates, fish, and green algae). Bioassay of leachate samples obtained from bulk tire crumb before and after aging revealed a 59% reduction in toxicity in leachates recovered

Table 1. Results of in vitro genotoxicity assays of solvent extracts of fresh tire crumb.

Sample	Ames Fluctuation Assay TA 98	TA 100	TA 1535	TA 1537	SOS Test	Mutatox
			Without Liver Activation			
Tire #1	NT	NT	NT	NT	NT	NT
Tire #2	NT	NT	NT	NT	NT	NT
Tire #3	NT	NT	NT	NT	NT	NT
			With Liver Activation			
Alberta Environmental Rubber Products No. 1	NT	MT	MT	MT	NT	NT
Tire Recycling No. 2	MT	NT	NT	NT	NT	NT
Midwest Tire No. 3	MT	MT	NT	MT	NT	NT

Note: MT = marginal toxicity; NT = absence of toxicity.

from crumbs that had been in place on playgrounds for three months. The second phase of testing, which used inoculation of tire crumb leachates in the laboratory with nutrients and sewage seed followed by continuous aeration for 5 days, resulted in significant (73–86%) reductions in toxicity.

Table 3 presents the results of calculations of the PEEP index from the data. In all instances except one, the PEEP index was determined to be less than 3, which is considered acceptable by Environment Canada.[17] In the case of the schoolyard material, which was freshly installed and kept in place for three months, the PEEP index was only marginally greater than 3 (3.2). With further aging in place or treatment before installation, this value should drop below 3.

DISCUSSION

An exposure assessment performed to address the potential health risks to children playing in facilities where tire crumb is used as ground cover concluded that there was little potential for an exposure sufficient to cause adverse health effects in children. Genotoxicity testing of tire crumb samples following solvent extraction concluded that no DNA- or chromosome-damaging chemicals were present. This suggests that ingestion of small amounts of tire crumb by small children will not result in an unacceptable hazard of contracting cancer.

These findings indicate that chemicals leaching from relatively fresh tire crumb may present a moderate toxic threat to aquatic species if the runoff is not diluted. However, this toxic activity is quickly degraded by natural processes, presumably by conversion of the chemicals responsible to nontoxic products. Conditions likely to produce runoff, such as rain and snowmelt, are also likely to dilute the runoff in receiving sewers, bodies of water, and groundwater by considerable volumes. Given that undiluted runoff is not likely and that three months is an outside estimate of the duration of toxicity, it is doubtful that tire crumb would present a significant risk of contamination in receiving surface waters or groundwater.

ACKNOWLEDGMENTS

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Table 2. Initial results of species-specific assays for aquatic toxicity potential of fresh tire crumb.

Test	Toxic Units (100/LC_{50} or EC_{50}) Alberta Environmental Rubber Products No. 1	Tire Recycling No. 2	Midwest Tire No. 3
Microtox	15.4	8.9	7.3
D. magna	22.6	10	13.5
P. promelas	12.2	14.7	6.4
S. capricornutum	22	22.3	17
Total	72.2	55.9	44.2

Table 3. Results of species-specific assays and summary PEEP index for aquatic toxicity potential of tire crumb aged in place for three months.

Test	Alberta Environmental Rubber Products No. 1	Crumb Deployed in School
Microtox	14.9	11.7
D. magna	16.0	8.0
P. promelas	43.5	22.6
S. capricornutum	1042	412
Cumulative toxicity	1120	454
PEEP index	—	3.2

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Section 6:

Dutch National Institute for Public Health & the Environment

Answers to Questions on Harmful Substances in Artificial Turf Fields

Public Health, Social Welfare & Sport

Ministry of Social Housing, Regional Planning and Environmental Administration (VROM)
Department DGM/SAS
For the attention of Martijn Beekman
P.O. Box 30945
2500 GX THE HAGUE

Re
Rubber granules as infill material in artificial turf fields

Dear Mr Beekman,

On 22 May 2006, you asked the RIVM to react to comments made on Undersecretary van Geel's answer to questions in the Lower House (2050603510) on harmful substances in artificial turf fields. The comments raised the issue of the assessment of the health risks posed by rubber granules.

In connection with this request, the RIVM assessed the health risks of rubber granules (Appendix 1), and studied the answers to the questions in the Lower House. In supplement thereto, the environmental risks of rubber granules on sport fields were also broached (Appendix 2). Herein please find the conclusions and recommendations of the study.

Health risks of rubber granules
The RIVM has reached the conclusion that PAHs can in fact be released, to a small degree, from rubber granule particles in artificial turf fields, but on the basis of the available data, this does not seem to entail any health risk. Nor is there any risk from oral exposure to DEHP as a representative of the accelerator group. There are no data available for the other chemical substances that can occur in rubber granules so as to enable us to assess the health risk. Since there is no risk for PAHs, as the most harmful component in PAHs, it seems unlikely that this would be the case for other substances.

Answer to questions raised in the Lower House

> Question 4
> Second question: Can a conclusion be drawn on the basis of the TUV report, that skin contact with ground car tyre particles on artificial turf fields are hazardous for human health?
>
> Answer 4
> Second question: No, I think that the chance of harmful health effects from PAHs in rubber granules in artificial turf fields is negligibly small, for the following reasons:
> 1. the PAHs are absorbed in the matrix of the rubber granules, and do not leach;
> 2. carcinogenic PAHs occur in very small quantities, namely in parts per billion in rubber granules (0.03 ppb), according to a study commissioned by the European association of tyre manufacturers;
> 3. The staying time for people is relatively short, and consequently the time that one is in contact with the rubber granules is only small; and
> 4. The TUV report speaks about a safe skin contact of more than 30 seconds at a content of less than 10 mg/kg.

> The concentration of 0.03 ppb means a level of about one million times below the limit recommended in the TUV report. I consider such a margin safe enough.

The Undersecretary's conclusions about the health risks of rubber granules in artificial turf fields correspond with those of the RIVM. The assessment of the health risk was however conducted on other grounds; the following marginal comments can be made to the Undersecretary's arguments:

- Various studies have shown that PAHs leach to a very small degree in contact with water (see tables in Appendix 2). The leachability of PAH in water is not a good yardstick for determining health risks;
- The concentration to which the Undersecretary refers (0.03 ppb) concerns the total of the carcinogenic PAHs in a leaching test. The total content of PAHs in rubber granules made from car tyres is in the order of 14 to 112 mg/kg or ppm (see tables, Appendix 2); the share of the carcinogenic PAHs, concerns about 40-80%.
- In his answer to the questions raised in the Lower House, the Undersecretary refers to a TUV report which contains a recommendation for maximum admissible values for PAHs in devices and toys. This recommendation does not include the use of rubber granules in sporting fields. A correspondence between TUV and Kempeneers (2006) shows that the values are based on best practices for PAH containing electrical appliances; they are not based on toxicological tests of migration at indicated concentrations and contact times. This is a recommendation, not a TUV standard, which must be seen as an initial attempt to derive a standard.
- The Undersecretary compares the results from a leaching test with the indicated contents in the TUV report. For a correct comparison, this should have been the total PAH content in the rubber granulate (14-112 mg/kg, see above). In case of skin contact longer than 30 seconds (which is plausible when doing sports on a field), at such concentrations this recommendation can be exceeded.

Environmental risks of rubber granules

The RIVM came to the conclusion that the MAR value for surface water was exceeded for three substances, because these substances leached from the rubber granules to the surrounding surface water; for 4-t-octylfenol by a factor 6, and for copper and zinc by 14 and 25 respectively. The MAR is also exceeded for all PAHs by a factor of 2. Adverse effects on aquatic organisms cannot be excluded at such levels. The conclusions from the RIVM research correspond to the results of a comparable study from Norway (NIVA, 2005). The standard for zinc is exceeded also in accordance with the Building Materials Decree (Hofstra, 2006).

Recommendations

With these presents we want to express our concern about the use of rubber granules from shredded car tyres on artificial turf fields. Rubber granules contain a large number of chemical substances which can leach into the surrounding surface water. In view of the provisional results of this study, drainage water must not be discharged directly (untreated) into the surface water.

The assessment of the health and environmental risks is based on a limited set of "exposure data."

- Additional information on the availability of chemicals from rubber granules upon dermal and oral exposure can provide further support for the provisional conclusion that there is no health risk from using rubber granules in artificial turf fields.
- Additional information for the assessment of the current concentration of compounds in the aquatic environment, will reduce considerably the uncertainties in the analysis of the environmental risks.

Kind regards,

Dr. J.M. Roels
Head of Substances Expertise Centre

Appendix 1

Health risks

1. Introduction

At the request of the Ministry of Regional Planning, Housing and Construction and the Environment (known by the Dutch acronym VROM), the following questions are answered:

- In which concentrations do PAHs occur in rubber granules? In ppb order or much higher?
- Are PAHs released from rubber granules upon contact with the skin during sporting activities? In reply to questions in the lower house, the undersecretary stated that PAHs do not leach.
- How do you assess the exposure time?
- Is there any real health risk from exposure to rubber granule particles?

2. In which concentrations do PAHs occur in rubber granules? In ppb order or much higher?

The total content of PAHs in rubber granules made of used car tyres is in the order of 14 to 112 mg/kg or ppm (see Appendix 2); the share of the carcinogenic PAHs is ca. 40-80%. It can be concluded that the PAH content in rubber granules is actually much higher (a factor of 100,000 for carcinogenic PAHs and a factor of 1,000,000 for total PAHs) than the 0.03 ppb which is mentioned in the reply to questions put in the lower house. The concentration to which the undersecretary refers (0.03 ppb) concerns the sum of the leached carcinogenic PAHs in a leaching test on water (BLIC, 2005).

3. Are PAHs released from rubber granules upon contact with the skin during sporting activities? In reply to questions in the lower house, the undersecretary stated that PAHs do not leach.

No information is available on the release of PAHs from rubber granules upon skin contact. There is a study available in which the migration of PAHs from car tyres is measured with the help of artificial perspiration (perspiration stimulant) (Danisch EPA, 2004). This study indicates that a demonstrable migration can be shown only for fluoranthene and pyrene. Migration is not however shown for benzo[a]pyrene, the most harmful (carcinogenic) PAH.

4. Exposure assessment

Exposure to chemicals present in rubber granules can occur through the skin (dermal adsorption), through the mouth (oral) and through breathing (inhalatory). No reliable information on rubber granules is available for any of these routes.

Background concentrations of benzo[a]pyrene in urban areas in Europe amount to about 1-10 ng/m3 (WHO, 2000). Additional inhalatory exposure to PAHs through evaporation of these materials from rubber granules does not appear likely in the atmosphere during sporting, given the low vapour pressure of PAHs. As rubber granules are coarse (size ca. 0.5 to 2 mm), the inhalation thereof is excluded. Inhalatory exposure is therefore not a source of an additional risk.

For exposure to the ground when playing, the National Institute of Public Health and the Environment assumes, for children aged 1 to 7, an average ingestion from hand-mouth contact of 100 mg per day (RIVM, 2002). For young children (18 months), an intake of 300 mg per day is assumed. In the Danish research study (Danisch EPA, 2004) cited in replying to the following question, an intake by children of 10 grams of polluted sand per day is assumed during half a year. This is a very conservative exposure scenario. In the present case, we are not dealing with ground or sand, but with rubber granule particles with a size of ca. 0.5 to 2 mm. The oral ingestion thereof does not seem very likely, but a value of 100 mg/day can be used here as a default for the oral ingestion of rubber granules.

No reliable scenarios are available for skin contact with rubber granules through sitting, lying, falling (sliding) on an artificial turf field. The Danish study (Danisch EPA, 2004) assumes 1 hour per day and exposed skin surface of 200 cm^2 for skin contact of children with rubber toys (old car tyres). This seems a considerable overestimation for the situation with rubber granules, since rubber granules are used as infill materials and direct contact with the skin tends to take place with the plastic fibres of the artificial grass than with the rubber granules.

5. Is there any real health risk from exposure to rubber granule particles?
As already indicated above, there is no information available to be able to assess the possible health risks upon contact with rubber granules. We therefore rely in part on data mentioned in the report of the Danisch EPA (2004). This report describes the possible risks of rubber toys in sandpits. It examines dermal exposure through direct contact with car tyres as well as oral exposure through the ingestion of polluted sand. The latter situation is not directly comparable with rubber granules, but it is illustrative for the assessment of a possible health risk.

5.1 Risk from dermal exposure
No migration could be shown in a test with a perspiration stimulant for benzo[a]pyrene, the most toxic PAH. It can consequently be concluded that there is no risk from dermal exposure on that basis. It would be more realistic, however, to assume a detection limit for the migration of PAHs of about 0.001 ng/cm^2 for the migration of BaP, as reported by the Danisch EPA (2004). By comparison with data from the Danish study, a systematic BaP burden of about 1-2 ng/kg of body weight through dermal exposure can be estimated. A benchmark dose (BMD10) for carcinogenic effects of 100 µg/kg of body weight per day is derived by WHO (2005) for BaP as a marker for the total carcinogenic PAHs in a mixture. This BMD10 corresponds to a dose that shows a 10% incidence on tumours in the exposed laboratory animal population. The exposure estimated above of about 1 ng/kg of body weight then corresponds to an additional lifelong cancer risk of 1 in a million. In other words, the risk from dermal exposure to PAHs is negligible.

Data are not available for the other substances present in rubber granules to enable any statement on the dermal risk. However, as there is no health risk for BaP as a marker for all PAHs and as the most toxic component in rubber granules, it appears unlikely that this would be the case for the other substances.

5.2 Risk from oral exposure
As indicated above, in the absence of real data, we assume an ingestion of 100 mg of rubber granules/day. Combined with a concentration of BaP in rubber granules of about 3 mg/kg, this corresponds to an intake of 0.3 ug BaP/person per day. When we assume (worst case estimate) that 10% of the BaP present in rubber granules can become available, the result, for a person weighing 60 kg is an oral exposure of 0.5 ng/kg of body weight per day. On the basis of the aforementioned WHO (2005) estimate of the cancer risk, an exposure of 0.5 ng/kg of body weight per day corresponds to an additional risk of 0.5 in a million. So the risk is negligible.

The Danisch EPA (2004) estimates the oral exposure to BaP from rubber toys to about 0.1 ng/kg of body weight per day. On the basis of the cancer risk estimate by WHO

(2005), this corresponds to an additional lifelong cancer risk of 1 in 10 million. This supports the conclusion that there is no risk for PAHs from oral exposure.

In addition to PAHs, other chemicals occur in rubber granules, such as phthalates (softening agents). For one of the most harmful phthalates, diethyelhexyl phthalate (DEHL), the risk from oral exposure to rubber granules can be estimated by analogy to the method used above. The rubber granule concentration for DEHP is about 20 mg/kg. At an intake of 100 mg and availability of 10%, this corresponds to an oral exposure of about 0.003 ug/kg of body weight per day. This is about a factor of 15,000 lower than the TDI derived by the EFSA (2005). In short, there is no health risk from oral exposure to rubber granules for DEHP (and the other phthalates) either.

General

Furthermore, it can be pointed out that the assumption of an oral availability of 10% of the chemicals present in rubber granules is very likely considerably overestimated. Results from leaching tests point to an availability in the order of 0.01%. In addition, a long-term daily exposure is assumed for the risk assessment (both dermal and oral). This too is very likely an overestimate of the situation in case of exposure to rubber granulate.

6. Conclusion

PAHs can in fact be released to a limited extent from rubber granule particles, but based on the available data, this does not lead to a health risk. There is no health risk for DEHP from oral exposure either.

Data for the other chemicals in rubber granules are lacking to enable a realistic assessment of the health risk. But as there is no health risk for PAHs as the most toxic component in rubber granules, it seems unlikely that this would be the case for other substances.

7. Recommendation

Additional information on the availability of chemicals from rubber granules upon dermal and oral exposure can provide further support for the provisional conclusion that there is no health risk from using rubber granules in artificial turf fields.

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RIVM 22 June 2006

Appendix 2

Environmental risks from the use of rubber granules on artificial grass football pitches

1. Introduction

Infill is the filling that lies on the top layer of the artificial turf field. Artificial turf football pitches often have an infill of sand and rubber. The infill's function is to stabilise the field and give the artificial turf specific properties, e.g. for sliding. Shredded car tyres or new EPDM ("aromatic free") rubber can be used for the rubber granules.

2. Formulation, chemical composition and results of leaching tests

Shredded car tyres are usually used. The composition of the infill rubber granules is then identical to that of the car tyres. The rubber of the car tyres contains a multitude of chemical compounds that provide the specific properties of the material. The composition of the rubber can vary widely depending on the specific proprieties that one wants to give to the rubber. The table below (Table 1) gives a picture of the difference in the composition (formulation) of rubber. The rubber industry works with formulations that indicate the used quantities of a certain product (additives) to produce a specific type of rubber. These are not only simple chemical compounds, but also a composition thereof, such as wax and process oils.

Table 1. Global composition (formulation) of the type of rubber for car tyres[1]).

Ingredient	Formulation A	Formulation B	Formulation C	Formulation D
polymer	18.3	88.9	46.8	55.9
carbon black	11.0		45.6	30.7
ZnO	0.5	2.7	1.4	2.8
Sulphur	0.4	2.2	1.2	0.1
Stearic acid	0.4	1.8	0.9	1.4
Anti-oxidant	0.2	2.7	1.4	0.8
Wax	0.2	0.4	0.2	1.1
Accelerators	0.1	1.3	0.8	0.3
Aromatic process oil	69.0		1.7	4.5

[1]) CIWMB (1996)

In addition, there are data relative to the chemical composition of car tyre rubber. To this end, the content of organic chemical compounds and metals in the rubber is determined by means of a chemical analysis. Table 2 provides a summary of the results of some chemical analyses of rubber granules for a number of organic compounds.

Table 2 Concentrations of organic compounds (in mg/kg) in rubber granules for car tyres.

Substance	Sample I[1)]	Sample II[2)]	Sample III[2)]	Sample IV[2)]	Sample V[2)]
Naphthalene	0.55	0.4	0.32	0.72	0.19
Acenaphthyline	5.6	0.6	0.79	1	<0.08
Acenaphthene	0.3	<0.2	<0.2	0.32	<0.08
Fluorene	<0.15	0.4	0.55	0.68	<0.08
Phenanthrene	4.3	4.8	5.9	5.8	0.43
Anthracene	0.83	0.6	0.55	0.76	<0.08
Fluoranthene	4.3	7.8	11	11	0.12
Pyrene	17	23	37	34	0.16
Benzo[a]anthracene	8.5	1.4	1.9	1.8	<0.08
Chrysene	6	2.2	2.2	4.2	<0.08
Benzo[b]fluoranthene	3.3	2.2	3.5	3.9	<0.08
Benzo[k]fluoranthene	2.5	0.4	0.55	1.5	<0.08
Benzo[a]pyrene	3	2.4	3.1	3	0.12
Dibenzo[a,h]anthracene	<0.47	<0.4	<0.2	0.44	<0.08
Benzo[ghi]perylene	6	3.4	5.8	5.1	<0.08
Indeno[1,2,3-cd]pyrene	0.21	0.8	0.95	1.4	<0.08
Total PAH (16)	62	51	74	76	1
Dimethyl phthalate		<1.0	<1.0	<1.0	3.4
Diethyl phthalate		<1.0	<1.0	<1.0	1.5
Dibutyl phthalate		3.4	2.6	3.9	1.6
Benzylbutyl phthalate		1.3	2.8	1.9	<1.0
Diethylhexyl phthalate		21	21	29	3.9
Di-n-oktyl phthalate		<1.0	<1.0	<1.0	3.2
Di-isononyl phthalate		57	78	-	-
Di-isodecyl phthalate		<1.0	<1.0	-	-
4-t-octylphenol		33.7	27.8	19.6	0.05
4-n-octylphenol		<0.005	<0.005	<0.005	<0.005
iso-nonylphenol		21.2	21.6	9.12	1.12

[1)] LUT (2004)
[2)] NBI (2004)

Table 3 provides a summary of the measured PAH contents, both the benzo[a]pyrene content and the total PAH content, in rubber and EPDM, from different studies.

Table 3: Summary of measured PAH contents (in mg/kg) in rubber granules and EPDM (Noordermeer, 2006; Hofstra 2006).

Type of sample	Reference	Benzo[a]-pyrene content	Total PAH content	Reference
Tyre powder	Norges Byggforskningsinstitutt	2.4	51	1
Tyre powder	Norges Byggforskningsinstitutt	3.1	74	1
Tyre powder	Norges Byggforskningsinstitutt	3	76	1
Tyre powder	TÜV Rheinland Group	<0.1	46	1
Treated tyre powder	TÜV Rheinland Group	<0.1	47	1
Tyre powder				
Passenger car	TNO	4.9	112	1
Tyre powder				
Lorry	TNO	3.0	90	1
Lorry	Intron Sittard	0.3	14	1
Passenger car	Intron Sittard	0.68	33	1
EPDM powder	Norges Byggforskningsinstitutt	0.12	1	1
EPDM	TÜV Rheinland Group	<0.1	1.2	1
EPDM	TÜV Rheinland Group	<0.1	0.45	1
EPDM	TÜV Rheinland Group	<0.1	0.14	1
EPDM	TNO	<0.05	<1	1
EPDM	Intron Sittard	<0.1	3.8	1
Field sample	INTRON	0.35	58	2
Field sample	INTRON	0.32	47.5	2
Field sample	INTRON	0.29	61.6	2
Field sample	INTRON	0.41	71	2
Field sample	INTRON	0.26	46.1	2

1) Noordermeer (2006)
2) Hofstra (2006)

In addition to organic chemical compounds, there are also metals in rubber (see Table 4), essentially zinc. Zinc comes from the zinc oxide added to the rubber, which is added as vulcanisation accelerator to the rubber during the production thereof.

Table 4. Concentration of metals (in mg/kg) in rubber granules of car tyres.

Substance	Sample I[1)]	Sample II[2)]	Sample III[2)]	Sample IV[2)]	Sample V[2)]
Arsenic	<9.95	<3	<3	<2	<2
Cadmium	<1.99	1	1	2	<0.5
Cobalt	<1.99				

Chromium	<1.99	<2	<2	<2	5200
Copper	32.1	35	20	70	<3
Iron	452				
Manganese	3.51				
Nickel	<1.99	<2	<1	<5	<5
Lead	<9.95	20	15	17	8
Zinc	174	7500	7300	17000	9500
Mercury		0.04	0.04	<0.03	<0.03

1) LUT (2004)
2) NBI (2004)

In addition to the determination of the content of organic compounds and metals in rubber granules, leaching tests are carried out (with rubber granules) to measure the degree of leaching (leaking) of substances from the granules to water. The leaching tests are conducted according to a NEN ISO 1457 standard protocol. Rubber granules are thereby brought into contact with deionised water at a ratio of 10 litres of water per kg of rubber granules. Leaching then takes place for a period of 24 and 48 hours under stirring for metals and organic compounds respectively (LUT, 2004 and NBI, 2004). After this period, samples are taken from the water and analysed for the different compounds.

The analysis of results from the leaching tests are given in Tables 5 and 6.

Table 5. Measured concentrations (in µg/l) or organic compounds in water of leaching test with rubber granules from car tyres

Substance	Sample Ia[1)]	Sample Ib[1)]	Sample II[2)]	Sample III [2)]	Sample IV [1)]
Naphthalene	11	<0.29	0.15	<0.01	
Acenaphthylene	<0.14	0.46	0.27	<0.01	
Acenaphthene	<0.5	<0.5	0.03	0.02	
Fluorene	<0.2	2.8	0.04	0.04	
Phenanthrene	0.1	<0.05	0.16	0.17	
Anthracene	<0.01	<0.01	0.03	0.03	
Fluoranthene	<0.01	0.09	0.06	0.06	
Pyrene	<0.05	<0.06	0.13	0.12	
Benzo[a]anthracene	0.03	<0.01	<0.01	<0.01	
Chrysene	<0.01	<0.01	<0.01	<0.01	
Benzo[b]fluoranthene	<0.01	<0.04	<0.01	<0.01	
Benzo[k]fluoranthene	<0.01	<0.01	<0.01	<0.01	
Benzo[a]pyrene	<0.01	<0.02	<0.01	<0.01	
Dibenzo[a,h]anthracene	<0.01	<0.01	<0.01	<0.01	
Benzo[ghi]perylene	<0.05	<0.06	<0.01	<0.01	
Indeno[1,2,3-cd]pyrene	<0.01	<0.01	<0.01	<0.01	

Total PAHs	<12.15	<4.43	<0.95	<0.54	
Dimethyl phthalate			0.6	1.6	
Diethyl phthalate			6.6	8.3	
Dibutyl phthalate			3.3	2.1	
Benzylbutyl phthalate			<0.1	0.3	
Diethylhexyl phthalate			5.1	5.6	
Di-n-oktyl phthalate			2.9	4.4	
Di-isononyl phthalate			2.7	2.2	
Di-isodecyl phthalate			<1.0	1.0	
4-t-octylphenol			3.6	2.95	50 – 0.2
4-n-octylphenol			0.043	<0.02	0.3 - 0.001
iso-nonylphenol			1.12	0.568	0.5 – 0.7

1) LUT, 2004

2) NBI, 2004

The total contents for PAHs (EPA-16) vary from 0.54 µg/litre to 12.15 µg/l (parts per billion, ppb). For benzo[a]pyrene, the contents measured in water are less than 0.02 µg/l. A recent research study (Hofstra, 2006) on the leaching of chemicals from rubber granules of Dutch artificial turf football pitches shows that the measured contents for PAHs (16-EPA) are in the range of <0.34; <0.40; <0.64; <0.11 and 0.45 for a water-granule ratio of 1:1 (LS=10). The total contents for PAHs (16-EPA) for production samples are between <0.44 and <0.94 µg/l (Hofstra, 2006). The measured contents correspond with the results of the Norwegian study (NBI, 2004) and the values reported by BLIC (2005). The higher deviating contents from LUT (2004) are caused in particular by high concentrations of certain compounds (naphthalene and fluorine).

Table 6. Measured concentrations (in µg/l) of metals and arsenic in water from the leaching test with rubber granules from car tyres.

Substance/	Sample Ia 1)	Sample Ib 1)	Sample II 2)	Sample III 2)	Sample IV 2)	Sample V 2)
Arsenic	2.27	1.69				
Cadmium	0.078	0.12				
Cobalt	5.33	5.81				
Chromium	2.95	5.96				<2
Copper	5.77	383				
Iron	0.284	0.462				
Manganese	56.4	5.57				
Nickel	4.31	1.37				
Lead	8.44	48.8				
Zinc	1310	7050	2290	1220	590	80
Mercury	<0.02	0.0386				

1) LUT, 2004
2) NBI, 2004

The study carried out by INTRON (Hofstra, 2006) reports zinc contents in eluent of 7500 – 6000 µg/l where the study was carried out according to DIN V 18305-7. This test is comparable with that used in (NBI, 2004). The tests carried out by INTRON are different. Here, what are known as column tests (NEN7383) are used (Hofstra, 2006), in accordance with the Building Materials Decree. This makes it possible to compare the results between the different leaching tests. Here, the ratio between the quantity of eluent (water) and rubber, the L/S ratio is important. In an L/S ratio of 10, the zinc contents vary from 400 to 1200 µg/l for production samples and from 1200 and 5300 µg/l for field samples. These values are comparable with the zinc concentrations reported by LUT (2004) and NBI (2004).

For samples Ia and Ib, the leaching tests are carried out at different pH values. In addition, the results of leaching tests with shredded car tyres are given for a number of substances (Sample IV). A comparison of the results of the leaching tests with rubber granules and shredded car tyres shows a higher extent of leaching for rubber granules. This is to be compared with the fact that the granule has a far greater specific surface (smaller particles), whereby the available surface for leaching is greater. Rubber granules concern particles of 1 mm to 10 mm in size. Cut and shredded car tyres concern pieces of 10-50 mm and 50-300 mm in size respectively, according to the European nomenclature, CWA 14243 (LUT, 2004).

3. Assessment of environmental risks

To get an idea of the possible effects on the environment, the concentrations measured in the leaching tests are compared with the surface water standards in force in the Netherlands, where the maximum admissible risk (MAR) and the target value (TW) are used (VROM, 2006). The MAR values are taken from the Substances and Risks website (RIVM, 2006). The maximum value of the measured concentration for each site is compared with the MAR. For substances with the same toxic action mechanism, the separate ratios between the concentration and the MAR can be added, for what is known as the "toxic unit" approach. This toxic unit is followed for the PAHs. The total (sum) for the PAHs is also given in the results (table 7.) The ratio between the concentrations and the MAR gives an impression of the possible effects for the environment (ratio > 1 is a potential risk).

In this case, "environment" refers to the receiving surface water. A situation is assumed whereby the drainage water from an outdoor artificial turf football pitch is discharged in a ditch situated nearby. It is assumed that the drainage water has the same concentration as the maximum measured concentrations of the leaching tests. In addition, it is customary, when assessing the risk of substances, to assume that water discharged in the surface water is diluted with a factor of 10. For a local risk assessment, it is further assumed that no biological or chemical degradation takes place.

The results of the comparison between the estimated concentrations in the surface water and the surface water standards in force in the Netherlands are given in Table 7.

The standards are expressed as total concentration in water. This comprises both the dissolved part as the part bound to the floating matter.

Table 7. Maximum concentration in the eluate, maximum estimated concentration in the surface water and ratio to MAR, for organic compounds.

Substance	Maximum concen (µg/l)	Concentration in water (µg/l)	MAR (µg/l)	Conc./MAR ratio
Naphthalene	11	1.1	1.20	0.92
Acenaphthylene	0.46	0.046		
Acenaphthene	<0.5	<0.05		
Fluorene	2.8	0.28		
Phenanthrene	0.17	0.017	0.3	0.06
Anthracene	0.03	0.003	0.080	0.04
Fluoranthene	0.09	0.009	0.500	0.02
Pyrene	0.13	0.013		
Benzo[a]anthracene	0.03	0.003	0.030	0.10
Chrysene	<0.01	<0.001	0.900	<0.001
Benzo[b]fluoranthene	<0.04	<0.004	0.025	<0.16
Benzo[k[fluoranthene	<0.01	<0.001	0.200	<0.01
Benzo[a]pyrene	<0.02	<0.002	0.200	<0.01
Indeno[1,2,3,cd]pyrene	<0.01	<0.001	0.400	<0.003
Dibenzo[a,h]anthracene	<0.01	<0.001	0.001	<1.00
Benzo[g,h,i]perylene	<0.06	<0.006	0.500	<0.01
Total PAHs[4)]				≥1.12-
				<2.31-
Dimethyl phthalate	1.6	0.16		
Diethyl phthalate	8.3	0.83		
Dibutyl phthalate	3.3	0.33	10 3)	0.03
Benzylbutyl phthalate	0.3	0.03	7.5 3)	0.004
Diethylhexyl phthalate	5.6	0.56	1.3 1)	0.43
Di-n-octyl phthalate	4.4	0.44		
Diisononyl phthalate	2.7	0.27	-	
Diisodecyl phthalate	1	0.1	-	
4-t-octylfenol	3.6	0.36	0.06 2)	6.00
4-n-nonylfenol	0.043	0.0043	0.33 3)	0.01
iso-nonylfenol	1.12	0.112	0.33 3)	0.34

MAR* this is the added MAR according to the formula below

1) Standard from the Water Framework Directive
2) Standard from the Water Framework Directive
3) Derived MAR based on the predicted no effect concentration (PNEC) from EU risk assessment reports (this is not an official national standard. This standard is comparable with MAR)
4). For the PAHs, the sum of the ratios between the concentration and the MAR is calculated by including and excluding the values that belong to concentrations below the detection

limit (<- sign). It should moreover be pointed out that standards are not (yet) available for all PAHs.

Metals and arsenic come to the environment from nature. The naturally present contents of these compounds are included in the MARs. The concentrations measured in the leaching tests are taken as the point of departure, and these concentrations are added to the natural background concentrations. For this reason, the MARs must be corrected with the natural background concentrations (BC), according to the following calculation

MARtotal = MARadded + BC
MARadded = MATtotal – BC

The results of the comparison between the estimated concentrations in the surface water and in the surface water standards in force in the Netherlands are given for metals and arsenic in Table 8.

Table 8. Maximum concentration in the eluate, maximum estimated concentration in the surface water, and ratio to MAR for metals and arsenic.

Substance	Maximum conc. (µg/l)	Concentration in water (µg/l)	MAR (µg/l)	BC (µg/l)	Conc./ MAR* ratio
4	2.3	0.227	32	1	0.01
Barium	11	1.06	230	76	0.01
Cadmium	0.12	0.012	2	0.4	0.01
Cobalt	5.8	0.581	3.1	0.2	0.20
Chromium	6.0	0.596	84	1.6	0.01
Copper	383	38.3	3.8	1.1	14
Mercury	0.039	0.00386	1.2	0.06	0.00
Nickel	4.3	0.431	6.3	4.1	0.20
Lead	49	4.88	220	3.1	0.02
Zinc	7050	705	40	12	25

MAR*: this is the added MAR according to the foregoing formula.

The comparison between the expected maximum concentrations in the surface water and the standards shows that the standard in the surface water was exceeded for three substances. For 4-t-octylphenol, this is by a factor of 6, and for copper and zinc by a factor of 14 and 25 respectively. For the total PAHs, the sum of the individual ratios is greater than one (≥1.1-<2.3) and thus the standard is likewise exceeded.
When the standard is exceeded for several substances, adverse effects on aquatic organisms cannot be excluded.

4. Comparison with other research
The conclusions from this research study correspond with a comparable study from Norway, NIVA (2005). In the latter study, zinc and 4-t-octylphenol came to the fore as possibly toxic for the aquatic environment owing to the use of rubber granules as infill, in particular for football pitches. The conclusion of this research on zinc corresponds to the results of the INTRON study (Hofstra, 2006), although it is worth pointing out that the conclusions from the latter study are based on standards from the Building Materials Decree.

5. Uncertainties in the risk assessment
The results from the leaching tests apparently reflect an extreme situation compared with the reality. The contact time of rainwater with the rubber granules is actually far shorter. The contact time during the leaching tests is 24-48 hours, whereas in reality, this will be far lower, and can thus provide a different picture of the quantity of leached substances. No judgement can be passed on the time-dependency of the leaching on the basis of the leaching tests, however. In addition to the time aspect, there is also the fact that the ratio between the quantity of granules and water is actually much higher.

Furthermore, exposure in the surface water takes place only during short period (during rain showers). On the other hand, a dilution factor for ditches during rain showers may be smaller than the factor of 10 used. However, the factor 10 is based on long-term effects (and not soon after rain showers per se), which again supports the application of the factor 10, because the standards are likewise based on long-term effects.

It is assumed that 100% of the substance in the surface water is 'bioavailable.' In the case of metals, only a part of the substance will actually be bioavailable (and thus toxic) for organisms. This has to do with the bonding etc. of the metal ion with other particles in the water. There is always more knowledge available for metals to apply a concrete correction for bioavailability. This correction depends on a number of abiotic parameters in the water, for instance pH, hardness and the quantity of dissolved organic carbon (DOC). The bioavailability correction has still not been "officially" introduced in the Netherlands, however, and is not applied in this study.

6. Recommendations

The following recommendations are made:

• In addition to the afore-named substances, there are also other compounds that occur in rubber, such as anti-oxidants and accelerators. A good foundation of the exposure data found in the literature (BLIC, 2005) is still lacking for these substances. An initial, provisional analysis has shown that, for a number of chemical compounds (e.g. aniline), the measured concentrations in (ground)water are higher than the PNEC (= MAR). The PNECs used here come from the risk evaluation reports (RARs) drawn up by the EU. It is therefore advisable to examine thoroughly other substances that occur in rubber. These substances could contribute to the overall risk of rubber granule application in the aquatic environment.

• To get a better picture of the kinetics (time-dependency) of the extent of leaching, specific leaching tests must be carried out. These must rely on a more realistic situation for rubber granule application in artificial turf fields.

• To get a good picture of the actual exposure of the aquatic environment, the occurrence of rubber chemicals in the drainage water from artificial turf fields should be measured (monitoring campaign).

• Given the (provisional) results of this study, drainage water should not be discharged directly (untreated) in the surface water.

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Section 7:

FQC
Infill Health Statement

Recent reports have suggested a potential cancer risk from certain granulate in fills. In response to this a study has been made of the available publications relating to this issue. The list of publications that have been scrutinised is given below. The particular cause for concern is the presence of Polynuclear Aromatic Hydrocarbons (PAHs) in some rubber infill formulations. It is known that certain PAHs are potential human carcinogens. It is accepted that the vast majority of PAHs in the environment derive from the incomplete combustion of fossil fuels in particular diesel exhausts from truck and car emissions. The studies to date have concluded that "PAHs are not released or at most negligibly released from tyre abradate", The University of Dortmund Institute for Environmental Research 1997. "Epidemiological studies conducted by the Health Effects Institute, The World Health Organisation and other investigators do not implicate tyre wear particles in ambient air as contributing to human health effects (respiratory and cardiovascular diseases). "Tyre debris is found in diffuse roadside soils, but the published studies present no evidence for ecotoxic effects in or from roadside soil". In general tyre abradate is a much finer particulate than are the granules used as infill materials in Football Turf. The finer the particulates the greater the surface area and higher potential for chemicals to leach out of the rubber. The majority of the studies have been on these higher surface area particles and have concluded they are currently acceptable. The larger granules used in Football Turf will therefore have even less potential for emissions. A study undertaken by the Danish Ministry of the Environment concluded that the health risk on children's playgrounds that contained both worn tyres and granulate rubber was insignificant.

European Commission Opinion of the Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) ON Brussels, C7/GF/csteeop/PAHs/12-131103 D(03)

European Union Commission Report IP/04/208 Brussels 16th February 2004

European Union Commission 27th amendment to the Council Directive 76/769/EEC

TÜV Produkt und Umwelt Information 08/2005

Department of the Environment Investigation Denmark 2004

Goodyear Tyres 2003 Environmental Health and Safety Report

Chelsea Center for recycling and Economic Development University of Massachusetts Technical Report 2 Environmental Impacts of Recycled Rubber in Light Fill Applications August 1998

BIOLOGI Rapport, provtagningsären 96/97, 97/98, 98/99 Environmental monitoring in Stockholm Municipality Laboratory for Aquatic Ecotoxicology and Institute of applied Environmental research Stockholm University 2002

Perspect 110 Suppl 3 451-489 2002 Cancer risk assessment, indicators, and guidelines for polycyclic aromatic hydrocarbons

Gas and Particle Emissions from automobile Tires in Laboratory and Field Studies Rubber Chemistry and Technology, 52, 146-158 1978

Rubber Dust from the normal wear of tires Rubber Chem. Technol. 47, 1011-1037, 1974

The Determination of Rubber in Atmospheric Dusts Rubber Chem. Technol. 232-241 1974

EEA CORINAIR Summary Report Final Version. Report to the European Environmental Agency from the European Topic Center on Air Emissions 1997

Particulate air pollution with emphasis on traffic generated aerosols Rfiso R-1053(EN), Riso National Laboratory, Roskilde, Denmark, 1999

IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Polynuclear Aromatic Compounds Part 1, Chemical, Environmental and Experimental Data, Vol. 32, Lyon, France P.39. 1983

IPCS Environmental Health Criteria 202, World Health Organisation Geneva 1998

The effects of motorway runoff on freshwater ecosystems: 1 Field Study. Env Toxicol Chem 14, 1079-1092 1995a

The effects of motorway runoff on freshwater ecosystems: 2 Identifying major toxicants Env Toxicol Chem 14, 1101-1092, 1995b

Tire wear as a source of PAH, UMweltbundesamt, Berlin CSTEE/2003/18/4

Source of fine organic aerosol 3. Road dust, tyre debris, and organometallic brake lining dust: Roads as sources and sinks. Environ Sci Technol 27, 1892-1904, 1993

Biomarker responses and chemical analyses in fish indicate leakage of polycyclic aromatic hydrocarbons and other compounds from car tire rubber. Environ Toxicol Chem 22, 2926-2931 2003

Fate and effect of Zinc from Tire Debris in Soil Environ. Sci. Technol. 2002, 36, 3706-3710

Section 8:

Incorrect Reporting

De Telegraaf on Research Report on Infill Used in Artificial Grass

Incorrect Reporting in De Telegraaf on Research Report on Infill Used in Artificial Grass

Wednesday May 31, 11:55 am ET

ALMELO, The Netherlands, May 31 /PRNewswire-FirstCall/ -- In its 31 May 2006 edition, the Dutch daily newspaper, De Telegraaf, once again reported a number of factual inaccuracies on the use of SBR rubber in artificial grass fields. The information in the report does not substantiate any of the statements reported in the intended article.

Principals and purpose

- The research was commissioned by leading companies in the artificial grass industry, the rubber processing industry, the ISA Sport test institute, the NOC/NSF and the KNVB.

- The purpose of the research was to obtain more detailed insight into the leaching of (mainly) metals in practice, and to initiate research into the purported harmful effects it may have on the public health. This stands in stark contrast to the statements carried in the report in De Telegraaf to the effect that the research targeted the "hazards posed by artificial grass". The balanced composition of the policy groups responsible for the research indicates that the industry is assuming full responsibility for its social position in this regard. The research is being conducted as a multi-phase project, whereby the first phase is dedicated to the generation of factual information.

Erroneous interpretation of conclusions concerning health and environmental aspects

- De Telegraaf claims that artificial grass definitely poses hazards with respect to health and environmental aspects. This is however not the conclusion drawn in the report in question.

- De Telegraaf further claims that, according to the report, zinc leaching is assuming 'disturbing forms'. The latter conclusion is by no means borne out by the report.

- The same applies to the statement, by De Telegraaf, to the effect that the levels by which leaching exceeds the limiting values (zinc) are 'alarming'.

- The potentially harmful substances mainly include zinc, volatile chemicals and polycyclic aromatic hydrocarbons. Artificial grass fields that use SBR rubber and are laid in accordance with industry standards fully comply with the limiting values for zinc leaching, as well as for polycyclic aromatic hydrocarbons levels. As no specific limiting values have as yet been determined for sports fields, the most relevant standards applicable in this case are the conditions of the Building Materials Decree (Bouwstoffenbesluit). The decree however stipulates that a minimum of 20 cm infill must be used, while, in practice, only 2-3 cm rubber infill is being used. In accordance with the standards prescribed by the Building Materials Decree (which are unrealistic for artificial sports fields) the only limiting values that are exceeded are those applicable to zinc leaching. In other words, these limiting values are not exceeded in the case of sports fields. It does however specify the need for more detailed attention to the issue of the correct use of rubber infill and good "housekeeping", whereby the infill must remain in place on the field.

- Although research has been conducted in several countries into the possible harmful effects

of rubber infill, with comparable results, only the Italian football federation has so far actually issued a ban on the use of untreated rubber granulates. To date, no other country has as yet considered this necessary.
- There is also no specific legislation available with respect to public health. The most relevant standards in that regard are the European standards applicable to the toy manufacturing industry and the recent recommendation issued by TÃV with respect to the directives for the evaluation of polycyclic aromatic hydrocarbons levels in fixed products.

The following are the conclusions drawn by the report with respect to health risks:

- All heavy metal levels are in compliance with the standards applicable to toy manufacturing and the risk of harmful effects on sportsmen and women is therefore negligible.

- The levels of polycyclic aromatic hydrocarbons fail to comply with the TÃV directives in the case of skin contact exceeding 30 seconds. The question as to whether extended skin contact is actually harmful has not been answered satisfactorily by any research projects conducted to date. Short periods of skin contact (whether realistic in the case of, e.g. a slide) are therefore deemed risk free.

- Indoor and outdoor use of rubber infill poses absolutely no risk to sportsmen/sportswomen or other parties concerned through inhalation.

Further research needs to be done on a number of aspects, including long-term skin contact with rubber infill. The conclusion, on the grounds of this research, to the effect that artificial grass fields with rubber infill are harmful to the public health, is therefore premature and incorrect. There is no direct reason to forthwith stop the use of rubber infill in artificial grass sports fields.

Role played by TenCate

TenCate (Euronext: KTC) is a participant in this research project because, as a market leader in the field of artificial grass fibres, it wishes to plead for the use of the safest possible system that will, at the same time, retain its play-technical properties for the longest possible period of time. By conducting this research, TenCate wishes to demonstrate its commitment to its social responsibility in the industry. The industry research contributes to the determination of enhanced quality criteria for artificial grass sports fields through the collection of the necessary factual information.

TenCate has been producing an alternative for rubber infill since 2004: This is partially done with a view to ensuring the full recyclability of these types of sports fields in the longer term. The new type of infill also retains its play-technical qualities in the long term. The system has been used for, among other applications, the training fields at KNVB, AZ and AFC Ajax and the main playing field at Heracles Almelo.

For more detailed information, please refer to the Ten Cate Thiolon website

www.thiolon.com

Conclusion

TenCate maintains the view that the use of rubber infill is fully responsible, both with respect to public health and the environment. TenCate will continue to strive for further optimisation and innovation with respect to continuing developments in the advancement of artificial grass systems. In the long term, TenCate expects alternative infill materials to be more easily available to the volume market.
www.tencate.com

Section 9:

PAHs & Other Organics in Tires
Origins & Potential for Release

BRYAN G WILLOUGHBY
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TECHNICAL NOTE: BGW/60623

Date: 23rd June 2006

PAHs AND OTHER ORGANICS IN TYRES – ORIGINS AND POTENTIAL FOR RELEASE

Background Material for the Standards for Artificial Turf Working Group

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1. PROLOGUE

These notes have been prepared to provide a background to discussions of the Standards for Artificial Turf Working Group. In particular they seek to show that the risk scenarios linked to rubber and its products are far from simple, and questions of what is safe should be qualified by considerations of the context intended – i.e. safe with respect to what?

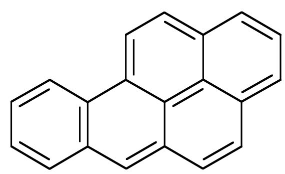
This does mean that care must be taken to avoid dealing with one problem only to provoke another. As is always the case, a balanced approach is necessary in risk assessment. The challenge is striking the right balance.

2. POTENTIAL HAZARDS FROM RUBBER

2.1 Polyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are widespread in the environment and are formed as formed as the result of the action of heat on organic materials, and especially alongside combustion.

Concerns over PAHs arise from the fact that some examples are potent carcinogens. An example of such is benzo[*a*]pyrene shown below.



benzo[*a*]pyrene
a polycyclic aromatic hydrocarbon

The carcinogenic PAHs are encountered amongst the less volatile examples of this class (e.g. typical Bps in excess of 450ºC).

A wide range of PAHs – including the carcinogenic ones – are found in the air – especially in urban air. They originate from various combustion sources (e.g. power generation, vehicular traffic, space heating or social activities such as cigarette smoking) and adsorb on smoke particles to become airborne (i.e. the carcinogenic PAHs are found on particulates <u>not</u> as vapours).

DEFRA routinely monitors PAHs levels in air. The results below are for mean levels for three carcinogenic PAHs at a site in Manchester.

Annual mean ambient concentrations (ng/m^3) of three PAHs in urban (Manchester) air (NETCEN, 1998)

	1991	1992	1993	1994	1995	1996	1997
benz[*a*]anthracene	2.5	1.1	0.6	0.8	0.3	0.8	1.1
benzo[*b*]fluoranthene	1.5	1.4	1.0	1.2	0.6	0.8	1.3
benzo[*a*]pyrene	1.8	1.6	0.7	0.8	0.4	0.5	0.8

Note these are average levels and the concentrations may vary widely from day to day (depending on the weather – i.e. dispersal factors). On one occasion in the outside air in rural Shropshire, I found 17 ng/m^3 of benzo[*a*]pyrene.

Possibly the highest levels of airborne PAH in the UK are routinely found in rural Scotland. These are near the aluminium smelter at Kinlochleven.

Given their widespread availability, human exposure to PAHs (and the carcinogenic ones) cannot be avoided. Some exposure scenarios are:

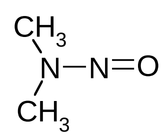
- inhalation of smoke particles
- ingestion of smoked, charred or char-grilled foodstuffs
- skin contact with soot.

Exposure does not stop at the risks from smokes and chars - as any particulate pollutant, once released into the air, can be transferred to other media. Hence the PAHs carried on smoke can settle on the ground (or vegetation) or be washed by rain into ground waters.

This means that, if you go hunting for PAHs (yes, even the carcinogenic ones), you will find them.

2.2 N-Nitrosamines

N-Nitrosamines are the N-nitroso-derivatives of amines, and a number are carcinogenic (e.g. N-nitrosdimethylamine).



N-nitrosodimethylamine (dimethylnitrosamine)

N-Nitrosamines figure prominently in concerns over cancer risks from rubber, although they have the potential to be formed whenever protein-containing material is roasted in a current of air. Beer, whisky and bacon contain carcinogenic N-nitrosamines.

Unlike the carcinogenic PAHs, N-nitrosamines are volatile. They can be formed during vulcanisation and released from the rubber (12 different ones are regulated for the German rubber industry). Over the last twenty years, the tyre industry has responded to worldwide concerns and effected large reductions in N-nitrosamine levels. Quite possibly they are now completely undetectable.

That may be the case for tyres – but is it so for EPDM? N-Nitrosamines can be particularly difficult to eradicate from EPDM.

2.3 Sensitisers

Most people can survive contact with rubber, but a few can show sensitive reactions. Potential sources of sensitisation are:

- the proteins in natural rubber
- the organosulphur and organonitrogen compounds from vulcanisation.

For those sensitised, the former gives rise to immediate (Type 1 allergy) hypersensitivity, whilst the latter gives rise to irritation and delayed (Type IV allergy) hypersensitivity. Together, irritation and Type IV hypersensivity are known as contact dermatitis. Contact dermatitis results in skin rashes, blistering, etc. Contact dermatitis is not normally associated with tyres or industrial rubber goods, but may be encountered where more prolonged skin contact is possible (e.g. elasticated garments, rubber gloves, condoms, etc.).

Type 1 allergy is only associated with natural rubber – it affects only a very few people, and the exposure scenarios are unusual (e.g. by inhalation of dusts which have been in intimate contact with the rubber). Nevertheless, since the individual may go into anaphylactic shock, the condition is potentially fatal. This has brought natural rubber into an uncomfortable focus. The UK market for natural rubber latex gloves has fallen considerably as a result.

3. EXPOSURE RISKS

3.1 Inhalation

The inhalation risk scenarios for PAHs from rubber were amongst the earliest to be studied (e.g. from the early 1970s) and provide some valuable lessons for any monitoring strategies.

The major source of the PAHs in tyre rubbers lie in the aromatic process oils used for plasticisation. These are oils have a boiling range 250-680ºC, and are waste products of refinery processes.

Plasticisation of tyre rubber enhances aspects of processing and product performance. Processing benefits include reduced energy consumption, and performance gains include higher hysteresis (and wet grip, etc.). It is always important to match the oil to the rubber and aromatic process oils are reserved for aromatic rubbers – i.e. the styrene-butadiene rubber (SBR) used extensively in passenger tyres.

The aliphatic EPDM (ethylene-propylene diene monomer) rubbers are plasticised with different oils – not aromatic types. Apart from perhaps decorative trim (whitewalls?), EPDM rubbers are not used in tyres.

The presence of carcinogenic PAHs in aromatic process oils makes the oils themselves carcinogenic. These oils carry the R45 (“may cause cancer”) labelling. Great care must be exercised in handling these oils in the rubber factory – skin contact must be avoided. The industry would like to stop using them but there are both cost and performance issues here.

Note it is the <u>oil</u> which is labelled R45 – but not the product tyre. After the oil is incorporated, the rubber is vulcanised. In simple terms, the effect of vulcanisation turns about two-thirds of the tyre into a single molecule. The oil itself is unchanged, but it is now trapped in this huge (infinite at the atomic level) molecular network.

One of the earliest studies of airborne PAH in tyre factories (started in 1973) quickly found that the results made little sense without comparative measurements on the outside air. Studies, over the remainder of that decade, in both the UK and USA, found that:

- no carcinogenic PAH was present in excess over ambient air levels

Additionally, laboratory studies have found,

- no PAH less volatile than pyrene (Bp 404ºC) in hot rubber fume.

These studies were conducted over a period of some ten years and resulted in a number of publications. They reveal that the process of volatile release from rubber can be viewed as a fractional distillation where only the most volatile oil components are released. Indeed, despite the fact that some three-quarters of the oil is aromatic, it is the smaller aliphatic content that dominates the volatile release from these oils.

By comparison, the aliphatic oils used in EPDM and other rubbers are a more prolific source of volatiles from hot rubber.

Odour issues are more problematic in that the specific source of the odour has not been clearly defined. One named candidate is 2-mercaptobenzothiazole (MBT), which is both an ingredient and a reaction product of rubber vulcanisation. Why this has been named is not clear – as MBT smells nothing like any rubber!.

The vapours released vary widely with the type of rubber and its temperature. One publication lists some 150 different species in the volatiles from rubber. Organonitrogen and organosulphur compounds are more likely to be released from hot rather than cold rubber.

At ambient temperature the volatiles released from the tread area of an SBR tyre are likely to be rich in alkenes (e.g. dodecenes) and ketones (e.g. methyl isobutyl ketone). Amines (e.g. dimethylamine, dibutylamine) are likely to be encountered in the volatiles from the inner (butyl liner) region of the tyre. The volatile released from natural rubber are likely to include natural alkenes (e.g. terpenes).

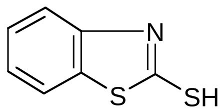
Volatile releases from rubber have been studied for over thirty years and much is already in the public domain. Nevertheless, the analyses are not unduly difficult to perform, and grade-related variations could form a part of any research strategy.

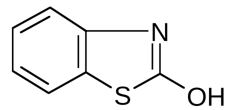
Of course, these considerations relate to volatile risks from rubber at temperatures up to those in manufacturing (e.g. up to around 200ºC). If the rubber is exposed to much higher temperatures, the volatilisation of higher boiling PAHs will become an issue. Certainly the fumes from burning tyres would be carcinogenic. But so are the fumes from vehicle exhausts, barbeques, etc., etc.

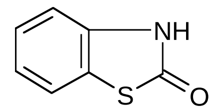
3.2 From Leachates.

The number of potential by-products from rubber vulcanisation increases significantly when involatile low molecular weight (i.e. potentially migratable) species are also included. One recent report to the Food Standards Agency on potential releases from food contact rubbers ran to over three hundred pages.

Additionally there is the potential for change after leaving the rubber, e.g. as in the hydrolysis of MBT to hydroxybenzothiazole and benzthiazolone.


mercaptobenzothiazole


hydroxybenzothiazole


benzothiazolone

Waste waters in tyre manufacturing plants have been the subject of study, where evidence for the presence of some of the lower molecular weight (non carcinogenic) PAHs can be found. Particular examples include naphthalene and various alkyl naphthalenes.

Issues regarding the migration of the higher molecular weight PAHs (carcinogenic) from tyres, tyre dust or tyre crumb have initiated much research (e.g. see Eric's synopsis), but studies in the field are inevitably confounded by the presence of such PAHs from other sources (i.e. washed out of the atmosphere). Laboratory extractions will yield more definitive data in terms of source-related effects – but balancing any contribution from rubber against that from other sources will be necessary. The overall findings to date seem to indicate that the contribution from the rubber is of no real concern.

Submerged scrap tyres are also used in the marine environment. No toxic risks have come to light, although there are increasing concerns over engineering issues and the stability of such structures in storms.

3.3 Skin Contact.

Section 2.3 above mentioned that contact dermatitis is not normally a problem associated with tyres. In any event, a Type (IV) allergic reaction usually subsides if there is no repeated contact.

Type 1 allergy is a different issue as emotions can run high. There is no evidence that fine tyre dust from natural rubber tyres can cause a Type 1 reaction – but the question has certainly been raised.

Section 10:

Recycled Rubber Nitrosamines Analysis

Tun Abdul Razak Research Centre
Brickendonbury, Hertford SG13 8NL.

Tel: 44 (0)1992 584966 Fax: 44 (0)1992 504248

Test Report

Sample(s) description: Recycled rubber powder	GR No. 06/035
	Date received: 19 Jan 2006
MCG Test Report No.R9955	Date of report: 25 Jan 2006

Recipient:	James B. Gray
Company name and address:	Lehigh Technologies 5308 River Ridge Drive, Suite 101 Brighton, MI 48116 USA

The various tests carried out, with their log identifying numbers, dates of testing and the initials of the person who carried out the tests, are tabulated below. UKAS-accredited tests are identified by their test reference numbers. Test references marked '*' denote tests which are not UKAS accredited and are not included in the UKAS Accreditation Schedule for our laboratory. Opinions and interpretations expressed herein are outside the scope of UKAS Accreditation

UKAS Test ref. no.	Test type by initials and test identifying run nos.	Date of testing	Operator
051 (FDA)	GC-NB-0564	24-25 Jan 06	PES / PCG

This report has been approved for release by

Sue Stephens; Head, Materials Characterisation
Ext 2005, E-mail *sstephens@tarrc.co.uk*

Report No. R9955 (RC16719)

The sample of recycled rubber powder was analysed as received for volatile N-nitrosamines according to our method reference 051 (FDA) in line with AOAC 1990, 987.05.

The following were the only N-nitrosamines observed in comparison with the set of reference standards which includes NDMA, NDEA, NDnPA, NDBA, N-PIP, N-PYR, and N-MOR and the results are reported as parts per billion (ppb) or micrograms per kilogram (μg/kg). The limit of detection is 1.5 ppb.

Material	Reference	Nitrosamines (μg/kg)
Recycled rubber powder	Lehigh PolyDyne 80/140 mesh	NDMA 2 N-MOR 2

Checked by: P C Gugan

Approved by: I S Stephens

Interpretation and Opinion

Using the most severe extraction methodology, the nitrosamines found were only slightly above the detection level. These low levels of NDMA and N-MOR represent a worst-case scenario with regard to the product. The dichloromethane extraction removes all volatile nitrosamines from the rubber, and so the results represent the maximum amount that could become airborne.

Section 11:

The Effects of Motorway Runoff on Freshwater Ecosystems

The effects of motorway runoff on freshwater ecosystems: 1. Field study

L. Maltby, D.M. Forrow, A.B.A. Boxall, P. Calow & C.I. Betton

Abstract

The effects of motorway runoff on the water quality, sediment quality, and biota of small streams were investigated over a 12-month period. Downstream of motorway runoff discharges there was an increase in the sediment concentrations of total hydrocarbons, aromatic hydrocarbons, and heavy metals and an increase in the water concentrations of heavy metals and selected anions. Hydrocarbon contamination of sediments was positively correlated with potential contaminant loading (i.e., length of road drained/stream size). The greatest effect was observed at Pigeon Bridge Brook, a small stream receiving drainage from a 1,500-m stretch of the M1 motorway. The dominant PAHs in contaminated sediment at this site were phenanthrene, pyrene, and fluoranthene, whereas the dominant metals were zinc, cadmium, chromium, and lead. Differences between the station upstream and downstream of discharges in the diversity and composition of the macroinvertebrate assemblages were detected in four out of the seven streams surveyed. However, there was no evidence of an effect on either the diversity or abundance of epilithic algae. The diversity of the aquatic hyphomycete assemblage was only affected at the most impacted site. Reductions in the macroinvertebrate diversity were associated with reductions in the processing of leaf litter and a change from an assemblage based on benthic algae and coarse particulate organic matter to one dependent upon fine particulate organic matter.

Reference

Maltby, L., Forrow, D.M., Boxall, A.B.A., Calow, P. & Betton, C.I. (1995). The effects of motorway runoff on freshwater ecosystems: 1. Field study. Environmental Toxicology and Chemistry, 14: 1079-1092.

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Web: www.cranfield.ac.uk/ecochemistry

Section 12:

Environmental Health & Safety Report

http://www.goodyear.com/corporate/about/environment/03-ehs/hottopics.html

2003 ENVIRONMENTAL HEALTH & SAFETY REPORT

HOT TOPICS

Goodyear keeps a pulse on global issues relating to the environment, health and safety of customers, associates and communities in which the company operates. Many times, the company takes sides on particular issues that are in the news or that face government scrutiny. For 2003, these Hot Topics include low-rolling-resistance tires, aromatic oils and tire wear particles.
To access these topics, either click on the following or scroll to find the articles:
- Low-rolling-resistance Tires
- Aromatic Oils
- Tire wear Particles

Low-rolling-resistance Tires
Low-rolling-resistance tires normally are used as original equipment on many vehicles to help auto manufacturers meet federal corporate average fuel efficiency (CAFE) standards. These U.S. mileage standards were adopted to reduce the use of fossil fuels and to improve the environment.

Some people have suggested that low-rolling-resistance tires should be adopted as the standard for all tires. However, low-rolling-resistance tires have a shorter life and are more expensive to manufacture than current replacement tires. We believe a full understanding of tire design trade-offs, life cycle impacts and higher cost is necessary.

Tire design
Tire design is based on balancing competing and conflicting objectives for each tire. The major objectives include wet and dry traction, ice and snow, ride, treadwear, rolling resistance and cost. Different tires are designed for different customers based on the characteristics they value most. Tradeoffs must be made to maximize any single characteristic.

Customers are familiar with these issues as they frequently hear advertising and base purchasing decisions on tire performance characteristics (snow and ice tires, wet weather tires, tires with premium ride and tires with long wear). Low-rolling-resistance tires can have reduced treadwear, less traction and higher costs than conventional replacement tires.

Life cycle impacts
Goodyear believes its products should be evaluated according to environmental impacts relating to materials used in their manufacture, the manufacturing process, their use and their disposal.

Because low-rolling-resistance tires have a shorter life, more new tires and more raw materials will be required to provide tires for the same vehicle miles. Low-rolling-resistance tires also produce more emissions during manufacture. And a shorter tire life ensures that more scrap tires will be produced. Opinions on low-rolling-resistance tires have focused on their fuel economy benefits without consideration for other phases in life cycle.

Economic Impacts

Economic analyses have focused on fuel cost savings, yet no detailed analysis has factored in higher manufacturing costs and shorter tire life. In addition, no definitive analysis has been conducted of other alternatives. For example, proper tire inflation maintenance is a low-cost alternative for improved rolling resistance and tire life. The Rubber Manufacturers' Association's "Be Tire Smart, Play your PART" program is designed to raise consumer awareness and improve tire performance.

Conclusions

There are currently inadequate environmental or economic data to support legislative requirements that all tires be low rolling resistance. In fact, legislating low-rolling-resistance tires is expected to have a detrimental effect on tire life cycle due to tradeoffs required to achieve low rolling resistance. Consumers would be expected to pay more for tires that provide less performance in other areas they consider important long life and traction.

Goodyear supports programs to research and test alternatives to determine the best life cycle and best economic solution. Until comprehensive studies addressing the entire life cycle of a tire have been considered and that data demonstrate the advantages of making all tires low rolling resistance, Goodyear will continue to provide a wide range of options for its customers.

Highly Aromatic Oils in Tires

Current scientific data does not support legislation or regulations to restrict the manufacture or marketing of tires with highly aromatic oils containing polynuclear aromatic hydrocarbons (PAHs). In addition, aromatic oils when incorporated into rubber or into tires do not pose health risks to humans, and their release into the environment is negligible.

It is recognized and supported that the emission of carcinogenic substances into the environment should be as low as possible to control any risks to human health and the environment. Existing research data indicate that during tire manufacture, exposure to aromatic oils is minimal to zero. Chemical analysis has been unable to detect any PAH release into the environment from tire debris.

Several reports pertaining to aromatic oils, including from the International Agency for Research on Cancer, point to other environmental sources of PAH, such as asphalt runoff, auto emissions, polluted air, cooking, wood smoke, and tobacco smoke among other sources. The Swedish National Chemicals Inspectorate report (June 1994) alludes to an environmental contribution, but is based solely on inaccurate theoretical assumptions and calculations.

Human risk?

The risk for high levels of PAHs in highly aromatic oils is the potential for skin cancer to develop in workers exposed to oils, with prolonged and repeated skin contact, where good hygiene is not practiced. In the rubber industry where aromatic oils are used as process and extender oils, the incidence of skin cancer has not been increased by the handling of oils during the manufacturing processes. The rubber manufacturing industry has taken measures to eliminate exposure risk during handling by the installation of enclosed systems.

Ratpan and Hayes (1989) performed animal skin-painting studies with polymers containing highly aromatic oils. No skin cancer developed during the 18 months of study. Also, there is no reported incidence of human skin cancer from exposure to these types of oil-containing polymers. Using laboratory tests (Ames in-vitro assays) similar to those tests used to help determine the carcinogenic potential of highly aromatic oils, organic extracts of tire wear debris did not show any mutagenic activity (Hannigan, 1994).

Environmental risk?

Current scientific knowledge indicates that zero to negligible PAHs are emitted into the environment from tire wear particulates as a consequence of tire tread abrasion. There is no reliable environmental scientific justification for prohibiting the use of highly aromatic oils in tires.

The "University of Dortmund, Baumann/Ismeier, Institute for Environmental Research" research project paper (1997) indicates that PAHs are not released or at the most negligibly released from tire abradate (debris). This study was performed under contract from the German Federal Office of the Environment.

L'Institut Pasteur conducted inhibition, mobility and mortality tests in 1996 following European Union protocols. The tests, using rubber powder buffed from passenger tire treads, indicated extremely low levels of aquatic toxicity for water leachate. Thus, the leachate material is not considered toxic to aquatic organisms.

Safety considerations

Tires are a key component in automotive safety. Tires enable the driver to safely accelerate, maneuver, and stop under a wide range of speeds, surface conditions and weather, while providing ride comfort and long wear. Highly aromatic oils contribute directly to tire performance, integrity and traction. These oils, therefore, play a critical part in tire quality and the safety of all users and passengers in motor vehicles.

Because tire integrity and the safety of the end user are paramount, it is essential that any mass change in oil or any critical component not be undertaken until a full and thorough evaluation is complete, and that safety has been fully demonstrated.

Tire technology issues

Numerous materials are blended with natural and synthetic rubber to make rubber tire components. The various components are used to form and construct a tire. The tire is then cured under high temperature to produce the final composite thermoset finished tires.

Goodyear is committed to producing new types of tire lines. Hundreds of Goodyear engineers and scientists constantly evaluate new materials and new combinations of old materials. Goodyear continually works to develop new tires that meet constantly increasing customer requirements and expectations, while decreasing the impact on the environment.

Goodyear continues to explore the use of low-aromatic oils and other substitute materials. When product performance criteria are satisfactorily achieved, all safety considerations are addressed, product quality is assured and life cycle issues finalized. Use of replacement oils then can commence.

Conclusions

It can be concluded that rubber tires contain PAHs originating from certain oils used in tire manufacturing, but there is clear scientific evidence that any release into the environment is negligible relative to other PAH sources. The European Commission's Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) supports this conclusion.

The CSTEE states that, "a reduction of the concentration of PAHs in tyres will insignificantly reduce the overall concentration of PAHs in the environment." [Brussels, C7/GF/csteeop/PAHs/12-121103 D(03)]. The CSTEE adopted the risk assessment for PAHs in extender oils and tires in its plenary meeting of 12-13 November 2003.
It also has been demonstrated that the risk of rubber workers developing skin cancer from exposure to highly aromatic oils contained in rubber is non-existent. Therefore, there is no scientifically based need to restrict the use of highly aromatic extender oils to produce tires.

Furthermore, it is Goodyear's Environmental Health & Safety policy to ensure our products are safe by using materials that will not cause harm to our workers or the environment. It is also our policy to comply with our global environmental, health, and safety standards and the laws of each country where Goodyear does business.
Tire wear particles

Goodyear has analyzed the published literature on the concerns to health and the environment produced by tire particulate emissions. Based on the published data and evaluations, Goodyear concludes that wear and abrade (coarse particles greater than 93 percent, fine particles less than 7 percent). The rate of treadwear is influenced by many variables, including the type of tire produced, roadway characteristics and driving styles. Studies conducted by Blok, l'Institut Pasteur and other investigators indicate that tire debris and fine airborne tire dust resulting from tire wear pose no significant environmental issues. Tire wear is a minor source of particulate matter, compared with tailpipe and road dust, and contributes 1.1 percent or less of the PM10 and PM2.5 from all sources in the European Union-15 countries (CEPMEIP, 2001).

Epidemiological studies conducted by the Health Effects Institute, the World Health Organization and other investigators do not implicate tire wear particles in ambient air as contributing to human health effects (respiratory and cardiovascular diseases).

Organic pollutants, including polycyclic aromatic hydrocarbons (PAHs) found in road dust and in airborne particulate matter, are derived primarily from vehicle exhaust and stationary combustion sources. Scientific data do not indicate that PAHs are released into the environment from tire debris.

Tire debris is found in diffuse roadside soils, but the published studies present no evidence for ecotoxic effects in or from roadside soil. Also, tire wear debris in roadside soils is degraded by bacteria and fungi and/or decomposed by oxygen and sunlight.

There are no definitive data to associate road runoff leachate with adverse effects on aquatic ecosystems.

The hypothesis that extractable dry natural rubber protein causes allergic reactions or contributes to asthmatic conditions has been refuted with scientific data.

Conclusion
Based on all available scientific data, Goodyear concludes that tire wear particles pose no environmental concerns.

Section 13:

Cancer Risk Assessment, Indicators & Guidelines for Polycyclic Aromatic Hydrocarbons in the Ambient Air

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12060843&dopt=Abstract

Cancer risk assessment, indicators, and guidelines for polycyclic aromatic hydrocarbons in the ambient air.

Bostrom CE, Gerde P, Hanberg A, Jernstrom B, Johansson C, Kyrklund T, Rannug A, Tornqvist M, Victorin K, Westerholm R.

Swedish Environmental Protection Agency, Stockholm, Sweden.

Polycyclic aromatic hydrocarbons (PAHs) are formed during incomplete combustion. Domestic wood burning and road traffic are the major sources of PAHs in Sweden. In Stockholm, the sum of 14 different PAHs is 100-200 ng/m(3) at the street-level site, the most abundant being phenanthrene. Benzo[a]pyrene (B[a]P) varies between 1 and 2 ng/m(3). Exposure to PAH-containing substances increases the risk of cancer in humans. The carcinogenicity of PAHs is associated with the complexity of the molecule, i.e., increasing number of benzenoid rings, and with metabolic activation to reactive diol epoxide intermediates and their subsequent covalent binding to critical targets in DNA. B[a]P is the main indicator of carcinogenic PAHs. Fluoranthene is an important volatile PAH because it occurs at high concentrations in ambient air and because it is an experimental carcinogen in certain test systems. Thus, fluoranthene is suggested as a complementary indicator to B[a]P. The most carcinogenic PAH identified, dibenzo[a,l]pyrene, is also suggested as an indicator, although it occurs at very low concentrations. Quantitative cancer risk estimates of PAHs as air pollutants are very uncertain because of the lack of useful, good-quality data. According to the World Health Organization Air Quality Guidelines for Europe, the unit risk is 9 X 10(-5) per ng/m(3) of B[a]P as indicator of the total PAH content, namely, lifetime exposure to 0.1 ng/m(3) would theoretically lead to one extra cancer case in 100,000 exposed individuals. This concentration of 0.1 ng/m(3) of B[a]P is suggested as a health-based guideline. Because the carcinogenic potency of fluoranthene has been estimated to be approximately 20 times less than that of B[a]P, a tentative guideline value of 2 ng/m(3) is suggested for fluoranthene. Other significant PAHs are phenanthrene, methylated phenanthrenes/anthracenes and pyrene (high air concentrations), and large-molecule PAHs such as dibenz[a,h]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3-cd]pyrene (high carcinogenicity). Additional source-specific indicators are benzo[ghi]perylene for gasoline vehicles, retene for wood combustion, and dibenzothiophene and benzonaphthothiophene for sulfur-containing fuels.

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Section 14:

ETRMA

Section 15:

VACO

Use of rubber granulate in play-grounds forms no relevant risk to children or the environment; Prolonged daily skin contact with rubber tyres does not pose any relevant health risk.

PRESS RELEASE, 20 June 2006

RUBBER GRANULATE FROM RECYCLED CAR TYRES IS SAFE FOR PEOPLE AND THE ENVIRONMENT

Recent reports in the media have created uncertainty about the risks to health and the environment associated with the use of rubber granulate (tiles) on sports fields and playgrounds. However, new and existing studies conducted by various independent institutes show that rubber granulate used as infill material does meet the statutory requirements for health and the environment. This should dispel any doubts sportspeople and parents may have about health risks.

For years, tyres used all over the world have been recycled into rubber granulate and used in all kinds of products such as rubber playground tiles, in athletics tracks and as infill material for artificial turf fields and lawns. These applications help prevent unnecessary injuries.

In recent months, INTRON Certificatie B.V has carried out research into the risks to health and the environment associated with the use of rubber granulate in artificial turf sports fields. The research was commissioned by the builders of sports fields and DSM and set up under the supervision of a committee on which the VACO Association also had a seat. The research programme comprised both experimental studies of the chemical composition and leaching of rubber granulate, and literature studies of existing reports and articles on risks to health and the environment. The experimental research included an assessment of the leaching out of substances over a period of 100 years, in accordance with the guidelines of the Building Materials Decree.

The main conclusions of INTRON's research are:

- The rubber granulate meets the Building Materials Decree requirements regarding chemical composition and the leaching out of substances. This assumes the layer thickness of 2 to 3 cm applied in practice. It should be noted, however, that the Building Materials Decree does not cover rubber granulate but only stony building materials.
- The rubber granulate meets the standards set for heavy metals and the Toys Decree.
- On the basis of the available literature, it can be concluded that no health risks are posed by breathing in or brief skin contact.

Although the VACO Association is satisfied with these conclusions, it believes that the INTRON research does not provide sufficient information on the possible risks of young children eating rubber, prolonged skin contact with rubber and the possible toxicological effects of substances leaching into the environment. As a result, the VACO Association commissioned additional literature research of scientifically substantiated toxicological studies on the subject. No studies showing that rubber granulate poses a risk to health and the environment were unearthed. However, two studies were found that concluded the following:

- the use of rubber granulate in playgrounds forms no relevant risk to children or the environment. This study also looked at the dangers of eating rubber granulate, University of Alberta, 2003.

- prolonged daily skin contact with rubber tyres does not pose any relevant health risk, Danish Technology Institute 2005, commissioned by the Danish Ministry of the Environment.
  NB! It may take some time to download this file (8.09 MB)

On the basis of INTRON's research and the recent research information produced by the independent scientific studies conducted in Canada and Denmark, the VACO Association is convinced that the products made of recycled car tyres by its members in the Netherlands are safe for people and the environment.

The VACO Association would like to emphasise that the use of rubber granulate in sports fields and the use of rubber tiles on playgrounds make a significant contribution to the prevention of unnecessary injuries among sportspeople and children.

The Dutch government is also extremely positive about the recycling of tyres and the use of rubber granulate as infill for artificial turf. The Ministry of Housing, Spatial Planning and the Environment (VROM) would like to see at least 20 per cent of the car tyres that are collected recycled into high-quality granulate. Since last year, VROM has classified rubber granulate for artificial turf fields that meet the ISA-M37.a standard as a non-waste product. Use of rubber granulate in artificial turf sports fields and rubber tiles on playgrounds are high-quality applications that make a positive contribution to Dutch environmental policy.

Jointly responsible for the environment-friendly collection and recycling of used car tyres, the VACO Association, the Dutch industrial branch association for the tyre and wheel industry (www.vaco.nl) and the Tyre & the Environment Association, the association of manufacturers and importers of car tyres (www.bandenmilieu.nl), are delighted with these conclusions. To sum up, the use of rubber granulates and rubber tiles poses no threat to people or the environment and make a positive contribution to safety on sports fields and playgrounds. Both organisations believe that this new research really opens up the way for the use of rubber granulates as infill material on artificial turf fields. Recycling tyres and using them as a raw material spares the environment and ensures the responsible use of scarce raw materials. The use of rubber granulates is safe for the surroundings, sportspeople and spectators.

Note for the editors - not for publication

1. For more information, please contact Jeroen Jongeling, Sector Manager of the VACO Association, telephone +31 (0)71 568 69 70, email: vaco@kcleiden.nl.
2. The text of this press release is also available as a Word file. For a copy, please send an email to subp@kcleiden.nl.

Section 16 :

Recycled Rubber Use for Sports Surfaces Problems & Research to Delineate Risk

Recycled Rubber Use for Sport Surfaces
Problems and Research to Delineate Risk

Prepared by Professor Nick Christofi, Pollution Research Unit
Napier University, Merchiston Campus, Edinburgh EH10 5DT

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The Problems

The health hazards, to humans and the environment, associated with the use of rubber crumb materials in artificial surfaces for playgrounds and sporting arenas have been identified to include:

- Leaching and chemical pollution of soils and groundwaters
- Inhalation of volatile constituents
- Skin contact and ingestion
- Abrasion of surfaces and particulate release

Leachate Problems?

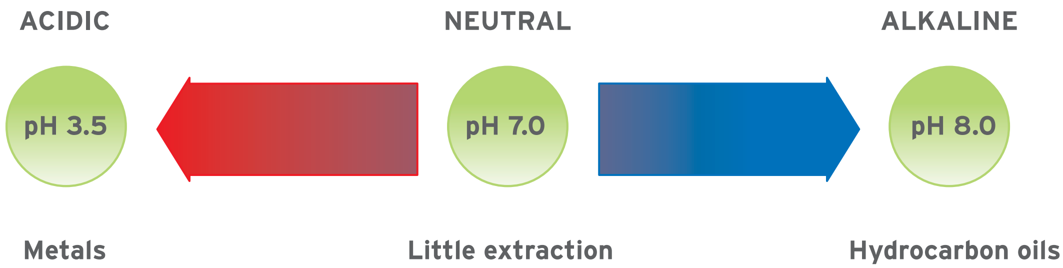
Rainwater percolating through the porous artificial rubber turf can lead to leaching of additives and other rubber constituents. Currently little information on techniques used and extent of leaching in real Playground and Sport artificial surfaces is available. It has been determined that rubber tyres disposed to landfill can add chemicals to leachate arising from the tyres constituents. Tyres are used in various environments including harbours where they act as bumpers. Hartwell et al (1998) explained that toxic substances appear to be leached from tyre surfaces and not from within the tyre matrix, and, that the use of tyres in higher salinity environments appears to pose little direct toxicological risk to native organisms. Unknown toxic substances were found to be present in leachates for waters of different salinities but no assessment was made regarding persistence, fate, transport, or possible bioaccumulative effects.

Approved soil leachate/extraction tests in accordance with standard procedures need to be carried out. Such tests are given in international standard ISO 15175:2004[1]. A number of leaching tests are available and include column leaching tests, lysimeter leaching tests, extraction or batch type tests and tank leaching tests for compacted granular materials. Important consideration for testing surfaces must be the examination of leaching from compacted turf and subsequent migration in the receiving soil environment. Soil physical chemical characteristics such as pH and ion exchange capacity can control speciation and binding and affect mobility of any released organic and inorganic chemicals. Biological activity can lead to the degradation of organic leachate reducing mobility that is ultimately controlled by water infiltration. The rate and extent of groundwater contamination will depend on the depth of the water table. The derived soil leachate test concentration would need to conform to water standards for the substance.

The leaching characteristics of tyre shred have been examined using a wide range of pH conditions. At neutral pH, iron and manganese levels increase as these metals are extracted from any exposed tyre reinforcing wire. These metals are generally present in soils, and the increases are generally not considered to be harmful to people or the environment. The rate of dissolution of wire increases under acidic conditions ($pH<7$), and zinc present within surface rubber can also be leached, but levels generally remain within acceptable parameters. Under alkaline conditions where $pH>7$ is encountered, organic compounds can be leached in trace quantities (Hammer & Gray, 2004). Fig. 1 shows the effect of pH on pollutant release.

1 ISO 15175:2004. Soil Quality- Characterization of soil related to groundwater pollution. British Standards Institution.

Figure 1. Effect of pH on metal and organic release from rubber crumb.



At neutral pH, dissolved metal concentration in soil water extracts is dominated by DOC- metal complexes. At low pH, dissolved metal concentration in soil water extracts is dominated by free ionic forms (e.g. Cu2+, Zn2+, Pb2+) followed by ion pairs (e.g. CuSO4, ZnSO4, PbSO4). Results suggest that as soil pH decreases, the availability and mobility of metal ions increases due to chemical form of metal ions in soil solutions (Reddy et al, 1995). Clay soils tend to be well buffered with little leaching of metals. Any released organics may migrate but there would be biodegradation processes (see e.g. Kanaly & Harayama, 2000) that would limit the transport of the low concentrations likely to be released from sport surfaces.

A recent testing of heavy metal presence and leaching from grass yarns carried out by an independent German Institute for BONAGRASS Yarns has shown low leaching with a conclusion that the artificial material may be used anywhere without restriction including sensitive areas. There is also a suggestion that the yarns can be recycled, burned and dumped as normal waste (www.bonayarns.com).

A recent briefing[2] to FIFA by Dr Eric Harrison examines the potential cancer risk of PAHs (polycyclic aromatic hydrocarbons) in certain granulate infills. The Danish Environmental Protection Agency carried out tests to examine PAH and aromatic amine concentrations in playground tyres as well as leaching of these constituents to sand and artificial sweat in contact with tyre materials (Nilsson et al., 2005). Their summary was that there was an insignificant risk in the use of waste tyres in playgrounds. Softeners and extenders are used to increase the workability of the rubber prior to vulcanisation. These are mainly petroleum oils and coal tar substances that will contain polycyclic aromatic hydrocarbons (PAHs) of environmental concern as they are implicated in induction of cancers. Plasticisers including thiophenols, other thiol compounds, and disulphides can be used to reduce the viscosity of the rubber during preliminary processing. These compounds are generally recovered by solvent extraction but can be found in proprietary rubber compositions. Tyres contain carbon black (that has traces of organics including PAHs associated with it) as a pigment and a filler to improve the tensile strength and abrasion resistance of rubber tyres. Titanium dioxide and silicon are also used. Carbon black represents by far the largest additive mass in a rubber tyre.

In an 11-month study, tyres bathed in rainwater at pH 4.0 and water at pH 7.0 leached a number of organic compounds shown in Table 1. Reddy & Quinn (1997) also showed the release of various organic constituents from rubber crumb including benzothiazole, 2-

2 Harrison, E. (2006). FIFA Statement on the potential cancer risk of certain granulate in fills. Unpublished Note (personal communication).

hydroxybenzothiazole and 2-(4-morpholino) benzothiazole.

Table 1. Laboratory tests to examine the long-term leaching products of tyres in distilled and acid rain water (Baumann and Ismeier 1998).

Substance	Concentration [mg/L]
2-Mercaptobenzothiazol	< 0.5
Benzothiazole	15 – 1972
2-Methylbenzothiazol	< 2
2-Methylthiobenzothiazol	< 2
Aniline	5.9 – 294
Dicyclohexylamine	< 35 – 218
Cyclohexylamine	< 1 – 423

A number of chemicals are used on artificial surfaces to improve the quality of the playing surface including salts to lower freezing point of water, fabric softeners to avoid pitch stickiness and chemical antiseptic cleaners. These will leach into soils but additionally may affect those using the surfaces following contact.

Inhalation of Volatile Constituents?

Numerous chemicals are used in the manufacture of rubber and rubber products. A comprehensive list with role is given in Appendix 6. Many of these chemicals are toxic or poisonous and have been shown to pose health hazards for rubber workers. These hazards can result in either acute short-term effects or can become chronic long-term diseases. Acute effects are caused by single or short-term exposures to chemical hazards. Chronic effects on the other hand result from continuous exposure to chemicals at concentrations lower than those shown to elicit acute effects.

All products made with SBR rubber, including automotive tyres have a distinct odour. This odour eventually dissipates leaving no detectable smell. The odour is caused by the various volatile organic carbon compounds used in the manufacture of the rubber (see Table 1). There is a paucity of data for air and soil emissions of rubber additives.A reason proposed as to why tyres give off odours is the photo degradation of rubber. Electromagnetic radiation, particularly light in the UV region, reaching the rubber can cause polymer degradation and release of smaller volatile compounds. In the absence of light and when surface coatings protect the rubber, this does not happen. Photodegradation by light is unlikely to play a major role in chemical release (OECD, 2004). It is generally accepted that rubber surfaces become dissipated of volatiles and that abrasion may expose surfaces with concomitant release of small concentration of tyre organics that would be insignificant. In addition, the chemicals in rubber do not have a high vapour pressure and inhalation would be negligible. It has been considered that low level exposure to pollutants, including PAHs, can lead to cancers and that this is a concern for artificial surfaces (see Appendix 1). Studies do not bear this out (see e.g. Birkholz et al., 2003).

Artificial surfaces may become colonised by algae (some of which produce toxins) and fungi producing aerial fruiting structures with numerous spores that can be released and inhaled. Is there any evidence that these can cause problems to humans? Regular cleaning should control biofilm formation.

Skin Contact and Ingestion?

Contact with a number of rubber industry chemicals can lead to dermatitis. Skin is usually difficult to penetrate with chemicals other than solvents that can penetrate the protective fat layer of the skin and enter the blood. Water is not an effective extraction medium for rubber and the concentration of chemicals likely to be extracted and presented to skin would be low. Skin exposure and entry would represent a low hazard.

The routes by which chemicals enter the human body are inhalation, swallowing and skin absorption. Ingestion of crumb would also represent a low hazard as eating of loose crumb would be improbable as would release of sufficient chemicals from crumb within the human body.

A recent report by Anderson et al (2006) indicated that there is no specific published information concerning exposure to rubber constituents from the use of rubber crumb products in playgrounds. Generally, studies have not been carried out to evaluate the use of rubber products in actual sporting and playground environments.

Abrasion of Surfaces and Particulate Release?

Rubber abrasion will lead to the release of particles, dust and expose more surfaces that may increase leaching of rubber additives. Most studies have looked at abrasion of car tyres on roads and transport to various environments including soils. A number of additives have been shown to be released from tyre materials. Fauser et al (2002) monitored aerial concentrations of tyre and bitumen particles near and at distance from roads. Concentrations decreased with increasing distances from roads and human and soil uptake can pose a danger. This danger is expected to be far greater than any danger posed by release from artificial surfaces.

Abrasion has been shown to significantly add to the release of persistent breakdown products of rubber additives, e.g. benzothiazole and methylated benzothiazole. In other studies, mass flow calculations have shown that runoff zinc, cadmium, copper and lead (constituents of rubber) from roofs and streets account for 50-80% of the total mass flow in domestic sewage (Boller, 1997).

Williams et al. (1995) studied aerial particulate pollutants and showed that black respirable rubber fragments may contribute to lung diseases. It requires to be demonstrated whether respirable particles are produced during normal use of artificial sporting surfaces, considering the high abrasion energy needed to generate fine particles.

Research Needs

The perceived problems are shown in Fig 2.

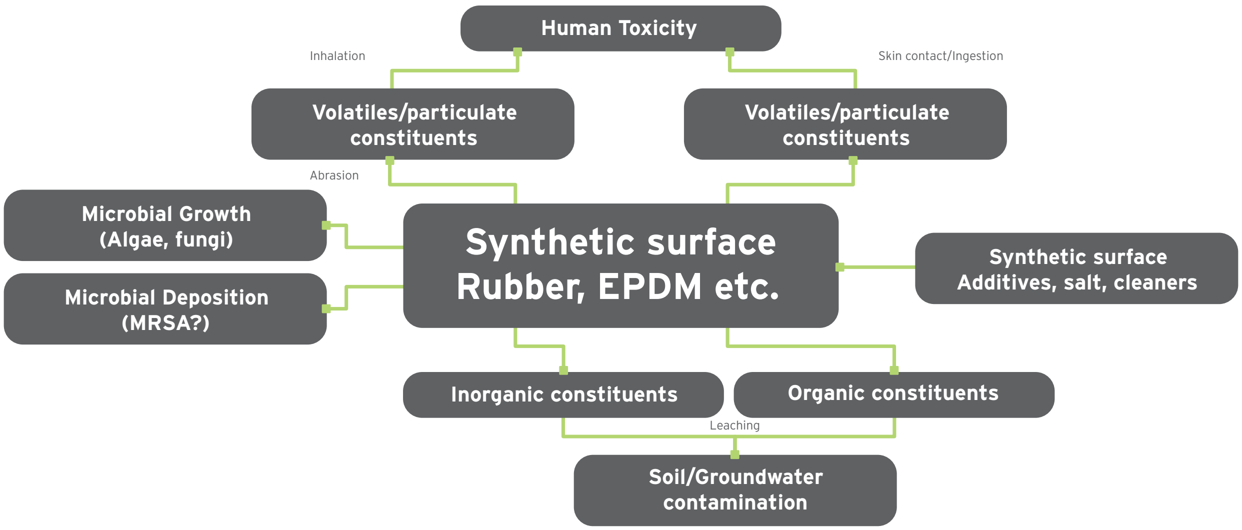


Figure 2. Perceived problems in using artificial granulates

Leachate Problems Analytical Considerations

• Leachate Tests:

Laboratory leaching tests can be carried out using predetermined sizes of crumbed tyres submerged into different solutions for periods of time after which leachate is analysed. This type of test can be used to indicate the types of contaminants released by crumbed tyre material. Information gleaned from laboratory leaching tests can then be used to design comprehensive field studies to evaluate environmental effects. Field studies using tyre material of various sizes embedded in soil with subsequent sampling of soils can be done. A recommendation would be to examine soils underneath playgrounds and sport fields where synthetic turf has been present for a number of years to examine for pollutants such as PAHs and heavy metals. Groundwaters in the vicinity can also be sampled downstream from fields and differences in chemical content compared with upstream levels. In addition, a survey should be carried out of cleaning agents used, frequency and analyses (chemical and toxicological) of major constituents in soils and groundwater samples.

- Examine soils and groundwater at existing synthetic turf site/control sites
  - Organic and Inorganic Analyses
    - Heavy metals including Zinc, Cadmium
    - PAHs
- Leaching experiments using various granulates
  - Organic and Inorganic Analyses
    - Heavy metals including Zinc, Cadmium
    - PAHs

Leaching experiments can be carried out by Professor Andrew Wheatley, School of Water & Environmental Engineering, Loughborough University.

Chemical analyses can be done by Professor Wheatley or by a NAMAS/UKAS Accredited Laboratory. With respect to the latter, ALcontrol Laboratories and the Eclipse Scientific Group are suggested.

● Toxicity Tests:
Aqueous samples from crumb/tile leachate experiments and extracts from soil and groundwater can be used to carry out toxicity tests utilising a range of bioassays covering different trophic levels including microbial, algal, invertebrate and mammalian toxicity testing. The toxicity data together with actual concentrations monitored in real sites will delineate risk.

Toxicology experiments can be carried out by the Pollution Research Unit, Napier University under the direction of Professor Nick Christofi and Dr Teresa Fernandes.

Inhalation of Volatile Constituents Analytical Considerations

It is very difficult to carry out tests on the effects of any volatiles released as these tend to be chronic effects given that small concentrations are likely to be released from abrasion and UV or other chemical processes. It is not recommended that this be considered for this study. Also it is more likely that any effects would have been recorded as a result of tyre use on roads. As far as we are aware there are no such toxicity documented.

Skin Contact and Ingestion Analytical Considerations

Leachate analyses in concert with leachate toxicology will enable an assessment to be made of the effects of chemical constituents to human health. One aspect that is a potential problem is the perceived increases in MRSA (Methycillin-Resistant Staphylococcus aureus) infections with increased use of artificial turfs. It is recommended that a study be made of existing surfaces to determine the presence of human skin inhabitants including S. aureus. Random swab sampling can be done and the use of differential media to detect for specific organisms. A survey can also be made to determine biofilms of algae and fungi on surfaces.

Microbiological Testing can be carried out at the Pollution Research Unit, Napier University by Professor Nick Christofi.

Abrasion of Surfaces and Particulate Release Analytical Considerations

There is a need to test the quality of air above an artificial playing surface to determine any risk from inhalation of particulates arising from abrasion. It is recommended that cumulative air sampling be carried out during a sporting event and that toxicity tests be used to assess the risk. Worst-case scenarios can be done in controlled environment chambers where abrasion is carried out over periods of time with concomitant air sampling. This can be done at Napier University where the chamber is situated in collaboration with Sport Labs and their abrasion equipment. Aerial pollutants generated by the abrasion tests and trapped on filters can be used for mutagenicicty and general toxicity using microbial biosensors, mammalian cell lines and macrophage assays.

● Chemical Analyses:
Trapped constituents of the filters can be tested for organic and inorganic substances trapped. This will determine types and quantities released and can be linked to toxicology data.

Chemical analyses can be done by ALcontrol Laboratories and/or the Eclipse Scientific Group.

- Toxicity Tests:

Trapped constituents of the filters can be extracted and used in toxicity tests where one carries out whole constituent testing that determined any additive, antagonistic and synergistic effects.

Mutagenesis (genotoxicity) and general toxicity testing can be carried out at Napier University under the direction of Professors Nick Christofi and Vicki Stone, and Dr Geraint Florida-James; Abrasion testing will be done in collaboration with Sport Labs, Livingston.

Frequently Asked Questions (FAQs) and Perceived Problems

Q. 1. Is cryogenically produced rubber crumb 'safer' than ambient SBR?

A. Cryogenically produced rubber contains particles with a smooth surface exhibiting different physical and chemical properties from mechanically ground rubber tyres. The smoother surfaces may reduce leaching of crumb chemicals but this needs to be determined.

Q. 2. Is EPDM 'safer' than SBR?

A. EPDM (ethylene propylene diene rubber) and SBR (Styrene Butadiene Rubber, a copolymer of polystyrene and polybutadiene) are thermosetting elastomers (See Appendix 2). The constituents used to produce these vulcanisates would have equal environmental concerns.

Q. 3. Is coated SBR safer than uncoated SBR?

A. This would depend on the stability (abrasion resistance) of the coating used and its formulation. Coating SBR would reduce rubber abrasion and photodegradation reducing the rubber odours.

Q. 4. What are the key components of tyres and are any of them hazardous / harmful?

A. The key components of rubber are shown in Tables 1 & 2 and a full listing with potential toxicity in Appendix 6. Many are hazardous but only in high concentrations. Rubber vulcanisates are specifically formulated to be stable and to resist wear, so it is unlikely that organic and inorganic constituents will migrate in large concentrations. Studies have shown insignificant environmental effects of leachates. A particular group of toxicants identified are the PAHs. Carbon black contains traces of PAHs some of which are known carcinogens. Some studies indicate that PAHs are strongly bound to carbon black presenting no hazard. Other studies, however, indicate that under certain conditions PAHs may be released and may present risk to humans.

Q. 5. Is EPDM technically 'better' than SBR?

Q. 6. What causes the smell of rubber surfaces and will it disappear?

A. Volatile organic compounds (VOC) used in rubber compounding formulations cause the smells. These would normally dissipate but abrasion may continue to release small concentrations into the air that continue to impart odour. Volatile degradation products of rubber may also contribute to the smell. The odours are characteristic of amines and sulphur-containing organic compounds (mercaptans) that have a very low odour threshold.

Q. 7. What is the difference between car and truck SBR and which is better / safer?

A. Car tyres are predominantly made using synthetic rubber (~47%) such a SBR whereas truck tyres consist mainly of natural rubber (~45% & ~11% SBR). Both tyres have similar organic and inorganic additives that may be considered hazardous (see Table 5).

Table 5. An example of a passenger car tyre composition. Truck tyres contain more natural rubber.

Compound constituent [phr] [wt-%]	Recipe	Recipe
Synthetic rubber butadiene (SBR)	80.28	43.63
Butadiene rubber (BR)	19.72	10.72
Fatty acid	1.97	1.07
Plasticiser	11.97	6.50
Waxes	1.69	0.92
Zinc oxide	3.10	1.68
Carbon black	60.56	32.91
Anti ageing agent	1.69	0.92
Accelerator	1.20	0.65
Sulphur	1.83	0.99
Total	184.01	99.99

[Phr]- parts per hundred

Q. 8. Since it is a recycled material, how can you guarantee that only truck tyres have been used and how can you guarantee the consistency between manufacturers tyres? (Usually asked in response following EPDM presentation where the Sec16:81consistency / componentscanbeguaranteedRecycledRubberUseforSportsSurfacesstatementhasbeenmade).

Crumb with a guaranteed production from used truck tyres should be sourced form accredited suppliers. There may need to be accreditation of crumb manufacturers with certification by SAPCA. A tyre guarantee mark can be incorporated on sidewalls of tyres.

Q.9.IsallEPDMthesame,oristherea Sec16:81bestRecycledRubberUseforSportsSurfacesEPDM?

Q. 10. Are there any personal safety issues playing on rubber filled fields?

A. The European Seed Association has highlighted problems associated with the use of artificial turf made from recycled rubber in promoting the benefits of using natural grass. These, in addition to direct injury from physically participating in a sport played on artificial turf, include general health and safety concerns. These have been identified (ESA, 2006) as:

- Increased incidence of MRSA (Methicillin-Resistant Staphylococcus aureus) bacterial infections. These may arise from turf burns and subsequent communal bathing. It could conceivably arise from MRSA and other bacteria deposited on synthetic surfaces from human sweat, blood, urine, sputum and vomit can be subsequently translocated.
- Foot blisters due to higher turf temperatures of artificial pitches.
- Toxicity problems from ingesting or licking rubber materials.
- Odorous compounds generated from the playing surface.
- Particulates (fines and ultrafines) released from surfaces following abrasion.
- Fire hazard.

Q. 11. Are there any differences in the behaviour of EPDM and SBR when exposed to high temperature e.g. flares?

Q. 12. In life cycle 'costs' which is more environmentally friendly, SBR or EPDM?

Both are synthetic rubbers with a range of chemical additives that could be a health problem if released.

Q. 13. Where else are recycled tyres used?

A. Appendix 4 provides a comprehensive list of uses of waste tyre materials.

Q. 14. How can the infill, SBR or EPDM, be 'recycled' when the pitch reaches the end of its useful life?

Q. 15. How long have these fields been around and have any long-term studies on leaching been carried out? If so what are the findings?

Q. 16. Are there any toxicity problems associated from ingesting or licking rubber turf materials?

Work carried out by the Danish Environmental Protection Agency suggests that there is an insignificant risk from licking or ingesting rubber granulates, as the release of substances such as PAHs to body surfaces outside or inside the body is very small and unlikely to cause toxic effects.

Q17. Is there any likelihood of contracting staphylococcal infections from playgrounds and sport surfaces made from recycled tyres?

Staphylococcus aureus can be found on the skin, hair and mucous membranes and very high concentrations are often found in wounds, sores or septic spots. These bacteria can be deposited onto surfaces and these can be transferred to people. This situation is not different to direct contact between people and transfer that is more likely. Survival of bacteria associated with humans on the turf surfaces is not known but SAPCA is testing this possibility.

Section 17:

Dutch Media Reversal

De Telegraaf

Serious blunder with artificial turf

"Scattered rubber granules safe for sports after all"

by Jouke Schaafsma

ARNHEM, Friday – Poisonous nitrosamine vapours floating above artificial turf pitches have probably never existed. According to the State Institute for Public Health (RIVM), artificial turf pitches sprinkled with rubber granules are in fact not damaging for health, as had been previously assumed.

Since RPS Advies came across carcinogenic nitrosamines in the air above artificial turf pitches in its assignment for the Hulpverlening Gelderland-Midden community health organisation, dozens of local authorities have banned use of the granules. Some of them have even gone so far as to spend tens of thousands of euro ordering replacement products.

Working on behalf of Arnhem council, the RIVM has conducted a larger-scale follow-up investigation. In the report published yesterday, it states that the initial examination of the problem was unreliable. The follow-up investigation, conducted by a different laboratory, indicates that there are no nitrosamines in the air.

The RIVM has also had the RPS Advies research bureau, which conducted the first tests, check the air once again. But the RIVM also filled a test vial that was clean and contained no nitrosamines at all. However, RPS Advies did come across nitrosamines in the air.

"There was an error in the analysis," states a spokesman from the Gelderland-Midden health department. "The method of examination used in the first instance has now been shown to be wrong. There is no problem at all with playing sport on artificial turf pitches." After the first examination, the department had stated that there was a risk.

RPS Advies is very unhappy with the RIVM's no-holds-barred conclusions and believes that it is unjustifiably being made to carry the can. "The foreign laboratory that we use still stands behind its conclusions," says spokesman Jan Willem Peters.

A further investigation is currently underway into the presence of heavy metals in rubber granules.

Nitrosamines in artificial football pitches pose no risk to health

30th November 2006

This is a joint press release from the State Institute for Public Health (RIVM) and the Hulpverlening Gelderland Midden community health organisation (HGM).

No nitrosamines have been found in various samples of air taken above artificial turf pitches that have been sprinkled with rubber grains. As a result, playing football on these pitches involves no health risk from exposure to nitrosamines. These are the finding of additional tests that Hulpverlening Gelderland Midden (HGM) has had carried out by the RIVM. As background to the issue, these substances were detected earlier this year in Arnhem above an artificial turf pitch. Both the RIVM and HGM doubt these earlier findings.

In this additional investigation, various artificial turf pitches in Arnhem were tested. To obtain as accurate a result as possible, the fresh analyses were not conducted by the RIVM alone. In this case, two laboratories analysed air samples independent to the Institute itself: the lab brought in this summer by HGM and a German laboratory with a great deal of experience in analysing nitrosamines. Neither the RIVM nor the German lab found any nitrosamines in the air samples. The other laboratory did, however, but that lab also found nitrosamines in clean control samples that contained no nitrosamines. It is for this reasons that both the RIVM and HGM have doubts about these and the earlier analysis results from this particular laboratory.

According to the RIVM, there is no health risk caused by exposure to nitrosamines while playing sport on artificial turf pitches that have been sprinkled with rubber granules. The reason for the follow-up investigation was the laboratory report of tests conducted in August 2006 by HGM on behalf of Arnhem council.

The RIVM had already concluded that based on published studies, exposure to carcinogenic plasticisers and PAKs did not constitute a danger for health. It seems that the quantity of PAKs, volatile aromatic hydrocarbons and heavy metals (including zinc) pose no health risk for people playing sport. However, the same research indicated that nitrosamines occurred in raised concentrations in the air above the pitch. Because the testing for nitrosamines had been only limited and Arnhem wanted to exclude any risk, HGM advised the city council to conduct additional research. HGM requested the RIVM to carry out these additional tests.

The research

Working in conjunction with HGM, the RIVM took readings in the air of four artificial turf pitches in Arnhem, including the sports field at Sportpark Rijkerswoerd. This is where the earlier research had been conducted. Readings were also taken at three other artificial turf football pitches, including the Johan Cruijff pitch, which has not been sprinkled with granules made from car tyres, but instead is treated with Thiolon® Infill Pro. These granules are manufactured specifically as rubber to be sprinkled on artificial turf pitches, rather than being produced from ground up tyres. The other pitches have rubber granules produced from tyres of varying ages.

A number of different readings were taken for each artificial pitch at various heights above the ground. The air samples were then tested not only by the RIVM laboratory, but also by the lab used by HGM for the initial testing, as well as by the German laboratory mentioned earlier. Each lab also analysed samples in which there were no nitrosamines present, the so-called ‘clean’ control samples.

These tests were solely about the health risks runs by exposure to nitrosamines and did not extend to the health risks of other substances or any environmental problems that the granules might pose. Based on additional information about the product, provided by the manufacturers and suppliers of the granules, a more complete picture of the possible risks was produced.

Section 18:

Netherlands Changes Position

For internal use

Key outcomes from the meeting with the Governing commission of the Intron project on environmental-and health aspects from the use of rubber granulate as in-fill material for artificial grass fields at Intron dd. 9 of March 2007.

The attendees where informed on the content of the discussions at the expert meeting on 7 of March. These where related to SBR as well as EPDM, TPE and TPV and the meeting will get a follow-up meeting at the request of VROM. VROM will take a decision in due time on what will/ will not be acceptable, what are the limit values/ norms to be applied); on the basis of this meeting, the dialogue with the sectors and their internal reflections. The members of the coordination/ governing committee will be kept informed on the progress made within the expert meeting.

Three departments of VROM are dealing with the SBR-problem:
- Soil and Water
- Substances and standards
- Waste

Martijn Beekman (VROM) stated that it is important that the sector is taking its own responsibility given the withdrawing government. This is valid for SBR as well as EPDM, TPE and TPV. This is amongst other the reason why VROM will therefore for the time being not take a position in respect to SBR. On basis for the following reasons:

- The amount of leaching and the risks of pollutions is too vague (soil, groundwater and surface water).
- On the international level virtually no countries an negative advice on the use or ban has been imposed from the government.
- The involved organization may also take measures to reduce the risks on pollution (e.g. the separate collection of drainage water, in order to avoid that this is automatically released to the surface water).

VROM suggest that every one should take their own decisions on basis of the report. The competent authority (represented by Mr Beekman) has the freedom and also the responsibility to make a correct assessment. Remarking some form of reservation in respect to the recent installation of the minister (Mrs Kramer), who didn't have the opportunity to look at the content of the report and therefore might respond differently at later stage. He will make a note for the minister. VROM is positive towards the proposal of the tyre industry to perform additional research to assess the real risks from the leaching of Zinc. This project will be performed in close dialogue with RIVM and VROM. VROM would like to see the results from this project in the coming months. Hereby he is thinking about measurements from draining water (FC Volendam has performed similar measurements with positive results) VROM wants to create more certainty on short term. The tyre industry has indicated that good research on the long-term leaching behavior of SBR in practical circumstances will require more time. In this project the positive results from projects in Switzerland and France will be taken into consideration. The research should address the complete build-up of the artificial grass fields and not only the SBR top-layer. Taking this into consideration this would require more uniformity in the build up of artificial grass fields. Ulbert Hofstra (Intron) will make an overview of the issues that can be achieved on short term and what would require more time.

Martijn and Rein Eikelboom (VROM) would also like to see further information on the environmental and health aspects of EPDM, TPE and TPV. The tyre sector has the opinion that the information on these materials should be comparable to the Intron report on SBR. Alberto Dozeman (DSM) informed that he can make available this information on a confidential basis (composition is confidential). Composition and leaching are known.

The "waterschappen" impose differnet demands to surfacewater. At this moment there is hardly an limitation on the use of zinc gutters. The leaching from these and the consequences for the surface water are compared to the leaching of zinc from SBR. VROM will in the near future think on the setting of leaching limits for zinc from Rubber granulates, because the current limits are not applicable and subsequently the Legislation and regulations are hardly applicable.
VROM has the opinion that every one who has the intention to install an artificial grass field has to apply for a permit at the " waterschappen" given the potential consequences on the leaching of Zinc. The "waterschap" will determine if a permit is granted (in theory these would already be required for houses with zinc gutters, However for administrative purposes this is not applied). VROM is taking into consideration that the "waterschappen" might require permits for the construction of artificial grass fields to a greater extend due to the content of the Intron report.

Alberto Dozeman (DSM) proposed to establish a shadow group(commission) similar composition to the current group (commission) for establishing a standards for in-fill materials to be applied on artificial grass fields. According to observation such activities have already been started at the European Level in (CEN/TC 217). Alberto stated that the composition of this commissions (many companies, no govenrments) leads to a wrong standard.

The tyre industry pleas that the research should be performed on the European level, given the fact that there also is a need for further information in other countries, while a lot of information from work performed in other countries is already available. Additionally, the tyre industry would like to compare the setting of standards in the Netherlands with those from other countries. In follow-up Rein Eikelboom (VROM) indicated that these are most likely not determined per Country, but often fall under the responsibility of the regional authorities (Local permits), As it is the case in the Netherlands where the local “waterschappen” are responsible for the surfacewater.

The constructors of the fields have an interest in the proposed follow-up research project by the tyre industry. The tyre industry have committed to take this up in their internal discussions.

The constructors create te impressions that by using other materials then SBR they are working better from an health and environmentally technical point of view. The Workgroup Construction products whishes to warn everybody (Make them aware) at the application of SBR. The tyre sector explicitly pointed out that specifically for SBR a lot of information is available and only very limited information on the other materials. Therefore it remains an open question whether one is better of when using the alternatives for SBR (e.g. Chrome Colored EPDM). Nevertheless it appears that Arcadis has already made it’s choice for TPE. Who on the basis of the results indicated in the Intron report, would rather like to see a ban on the use of SBR as they see it as their responsibility (duty of care). Grontmij is giving their customers the choice, which they have to take themselves on the basis of the available information.

The attendees have the opinion that the report will raise many questions in respect to the leaching of Zinc. However without the results of the proposed follow-up project, only less concrete information can be made available.

The version of the Intron report (Already circulated in digital format) d.d. 9 February 2007 is to be considered as final. Joeke de Jong will inquire if UEFA (Mr. Timmer) is willing to translate the report into English. The resume has already been translated by Intron (Already circulated in digital format). The Intron report and the English summary will be downloadable from the Intron website as soon as the embargo expires.

Henk Damen and Herman Poos will draft a draft press release on short term. The members of the Shadow group will be able to give their point of view on this draft until Monday 12 March 2007, 12h00. The press release will be spread by Intron. The Embergo on the content of the report will expire on Tuesday, 12h00. Te two Gentlemen will also make available to everybody a Q&A

Alberto Dozeman (DSM) Has serious objection that the press release would mention the foreseen follow-up project. As he doesn’t consider it useful to perform further research and that he is not involved in the research. It was determined that reference will be made towards the recommendations made in this report.

Leiden, 10 March 2007.

PRESS RELEASE (Concept)

To: Redaction
From: Intron, on behalf of the advisory commission of artificial grass fields
Date: Tuesday 13 March 2007
Concern: Artificial grass fields, filled with rubber particles

Independent research shows:
“No risk for the health playing on artificial grass fields”

There is no risk for the health playing on artificial grass fields that are filled with rubber particles.
A thorough investigation showed it Several substances have thereby been examined for suppliers and producers of artificial grass fileds, KNVB and combined Netherlands Olympic Committee and Dutch Sports Federation NOC*NSF.

The environment aspects have also been examined. It appears that 3 up to 20 years after construction of the fields, the standard of the building material decision for the leaching of zinc is exceeded. Intron, which have conducted the investigation, recommend conducting a deepening research project on the impact on the environment of leaching of zinc after erosion of the used material

The advisory commission of artificial grass fields moreover pleads for normative guideline at the ministry of VROM concerning the way in which those overshootings must be measured.

Representatives of the Ministries of VROM and Health, Welfare and Sport, the association Dutch municipalities, ISA sport and the player trade union VVCS also participated in the advisory commission beside the constituents. The research took place last year.

The research coordinated by Intron makes an important contribution to the discussions concerning the impact of artificial grass fields, both inland country and abroad. Numerous European countries have been already informed of the outcomes and the implications of the research.

In the Netherlands there is meanwhile 300 wide artificial grass fields lying in which ground rubber originating from tyres is processed

The sport organisation combined Netherlands Olympic Committee and Dutch Sports Federation NOC*NSF and the football association KNVB have with approval taken knowledge of the outcomes. Both the constituents and the players players worried about de possible health risks

Sports federations attach large value to the fact that it has become clear that no health risk has been linked to playing on this kind of fields.

Full report to be donwloaded from www.intron.nl

Not for publication
For more information you can contact Herman Poos, who coordinate press contact within the commission. He is available via at 06 22907374 and hpo@syntens.nl

Section 19:

Environmental Study Report

ENVIRONMENTAL AND HEALTH EVALUATION OF THE USE OF ELASTOMER GRANULATES (VIRGIN AND FROM USED TYRES) AS FILLING IN THIRD-GENERATION ARTIFICIAL TURF

Background

The production of artificial turf sports surfaces is a market in the throes of expansion. The company FIELDTURF TARKETT, a world leader in third-generation[1] artificial turf for the practice of football and rugby, installs more than 650 large sports pitches per year worldwide (approximately a hundred in France in 2006).

As part of the construction of such sporting surfaces (the earliest production on a global scale dates from 1995), elastic granulates and absorbents have been used as filling materials with the artificial turf fibres. Some of these granulates come from the granulation of used tyres (in France, recycled PUNR[2]: collected and sorted within the framework of the French Decree no.2002-1563 of 24 December 2002 concerning the elimination of used tyres), while other are manufactured specifically for this purpose (EPDM[3] or ETP[4]), and to a lesser extent some result from the recycling of EPDM (washing machine joints, car doors, etc.…).

Since the development of its first third-generation artificial turf applications, the company FIELDTURF TARKETT has chosen to favour the use of granulates from recycled materials for their filling needs, thereby permitting the reuse of roughly 11,000 tons of used tyre granulates in France on large sports pitches in 2006.

These third-generation artificial turf playing surfaces present numerous advantages for sports clubs and local authorities. The length of time for which they can be used is just about unlimited, with stable long-term performance levels, and the pitch requires limited maintenance in comparison with natural turf. The qualities of the systems developed by FieldTurf Tarkett are acknowledged by FIFA[5], UEFA[6] and national federations. FIFA and UEFA have permitted competition matches to be played on this type of surface since 1st February 2004.

In recent years and during 2006 in particular, press articles, sometimes relayed by certain sports federations, have, due to the presence of certain composites classed as dangerous in the initial manufacture of a tyre, called into question the harmlessness vis-à-vis human health of the use of recycled tyre granulates compared with virgin granulates. Several scientific studies have thus been conducted from an environmental and health perspective in several European countries with the aim of characterising the emissions of pollutants via gaseous and/or aqueous means.

Mindful of the importance of making sure of these aspects and in order to possess objective elements in the face of this type of publication, the main tyre manufacturers through the intermediary of the company jointly founded by them, ALIAPUR[7], in partnership with Fieldturf Tarkett and the ADEME, have undertaken starting in 2005 a programme of scientific study evaluating the environmental and health impact of the different material used as filling in artificial turf. These studies have been entrusted to the French *Groupement d'Intérêt Scientifique*, EEDEMS, which brings together the skills of the leading public and private bodies in these fields, most notably in the case of construction materials and products.

[1] Third-generation artificial turf appeared on the world market in 1995. Equipped with longer fibres (on average 60 mm), they are particularly characterised by a filling of sand and elastomer granulates of different types. The sporting performance of these surfaces rivals that of regularly maintained natural turf.
[2] Non-reusable used tyres
[3] Ethylene Propylene Diene Monomer
[4] Thermoplastic Elastomer (TPE)
[5] Fédération Internationale de Football Association
[6] Union of European Football Associations
[7] Company in charge of the recycling of 85% of the tyres on the French market in 2005; that is 31,550,000 tyres corresponding to 283,000 tons

This technical report contains the key facts from the studies and the general conclusions of the different evaluations. The document plan is as follows:

I. Interest and objectives of studies

The interest of the studies lies in the research and evaluation of possible environmental and health effects linked, on the one hand, to the transfer of meteoric water into the natural environment as a result of its percolation through the components of the sports surface and, on the other, to the gaseous emissions likely to be generated by the substances used in the composition of the sports surface.

Through the procedure adopted, three analytical approaches were carried out:

1. the chemical analysis for the determination of the concentrations of potentially polluting elements and substances present in the percolates collected after their transfer through the different constituent materials of the sporting surface,
2. the measurement of the ecotoxicity of the percolates collected after their transfer through the different constituent materials of the sporting surface,
3. the analysis of the volatile organic compounds (VOC) and formaldehydes emitted and their respective concentrations in am *"indoor"* sports surface usage scenario.

The concentration values obtained from the physicochemical analysis of the percolates was then compared with reference guide values (decree, acceptability values, etc.…). Those obtained by analysis of the VOC and formaldehydes emitted were used to conduct a Health Risk Evaluation study (HRE).

The experiments conducted, in this case the orchestrated monitoring of a football pitch and small-scale pilot studies on an experimental platform, correspond to the usage conditions of the pitches and to the development image of standards concerning other applications[8].

Eventually, the objectives of this study consist of:

1. obtaining reliable and precise information on the environmental and health impact of these applications,
2. providing responses to the main questions raised by the professionals, the sports federations, the institutions and the local authorities concerning certain elements and substances classed as representing a risk,
3. offering, in terms of the environmental and health effects, elements of comparison relative to the different types of granulates used as filling in artificial turf,
4. obtaining elements permitting the definition of standardised experimental protocols tailored to real usage conditions.

II. Evaluation of environmental impact on water

II.1. - The materials tested

The materials tested correspond to 3rd-generation artificial fibre turf from the FIELDTURF TARKETT range, combined with filling granulates of 3 different types:

- granulates from used tyres from the French market (PUNR),
- virgin EPDM granulates,
- ETP granulates.

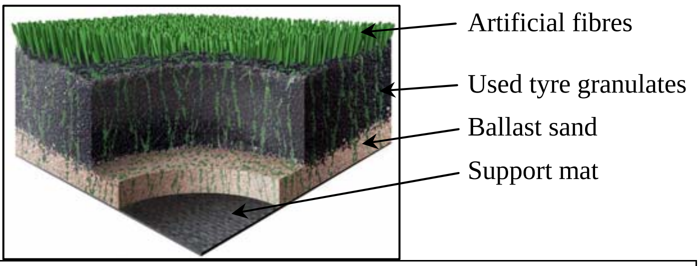


Figure 1: Vertical cross-section of a 3rd-generation sports surface (FIELDTURF TARKETT document).

[8] For example, the European standard on leaching tests EN 12-920 – Methodology for the determination of the leaching behaviour of a waste under specified conditions

The materials and products such as the ballast sand, the artificial assembly band and the polyurethane glue, used in the installation of a full-size sports pitch, have also been taken into account in the set-up of the experiments. Figure 1 shows the arrangement of the different constituent elements of the artificial turf sports surface.

The volumes of materials implemented per square metre in the different experiments presented below are 17.5 kg for the sand forming the ballast layer and 15 kg for each type of granulate considered.

II.2. - Two complementary approaches necessary for development of analytical protocols

In the aim of developing at the end of this study analytical protocols that correspond with the usage conditions permitting a characterisation of the environmental and health effects of artificial turf sports surfaces, two complementary analytical approaches were conducted in parallel.

The first approach, conducted on the EEDEMS experimental platform, consist of a controlled experiment in pilot scenario (on an intermediate scale between the laboratory and the true size) designed to compare the behaviour, from the point of view of the environmental and health impact, of 3 types of sports surfaces produced from 3 distinct types of granulate. A single type of artificial turf, with no granulates added, is used as control pilot.

The second approach consists of an experiment conducted *in situ* on a football pitch. The pitch, measured by means of a lysimetric box[9] placed beneath the artificial turf, contains used tyre granulates. This approach is carried out with the aim of providing complementary information as to the behaviour of the materials in the natural environment (subject to weather vagaries) and guaranteeing the representativity of the experiments conducted in pilot scenarios.

II.3. - Methodologies deployed

II.3.1. - Experiment *in situ*

An *in situ* device (Figure 2) was put in place during the construction of a training pitch in the Lyon region (69-France), to the rear of a goal area and on the periphery of the pitch (Figure 3).

This device consists of a lysimetric system made from a stainless steel sheet with a surface area of 2 m^2 and 10 cm in height covered by grating, buried in the support surface and laid out beneath the artificial turf in such a way as to collect the rain water that percolates through it (Figure 2).

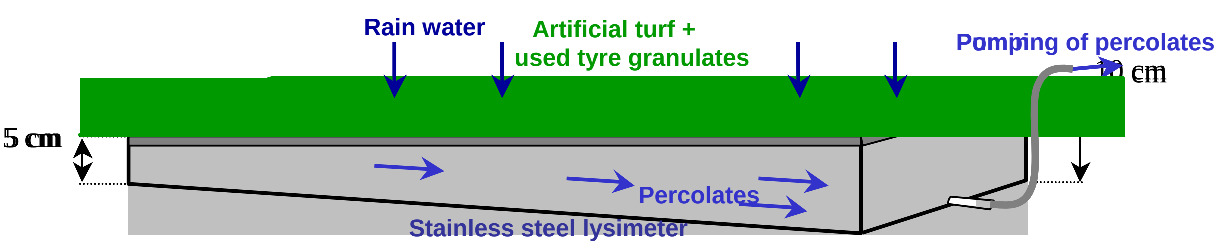


Figure 2: Diagram of the lysimetric system put in place on the football pitch.

[9] The simple lysimeter is generally presented as a cylinder or a tank, made of metal, concrete or plastic, with watertight sides and a base that allows the water to percolate so that it can be collected while measuring the flow rate and different parameters. It can be placed *in situ* (on the pitch to be studied) or *ex situ* (in the laboratory).

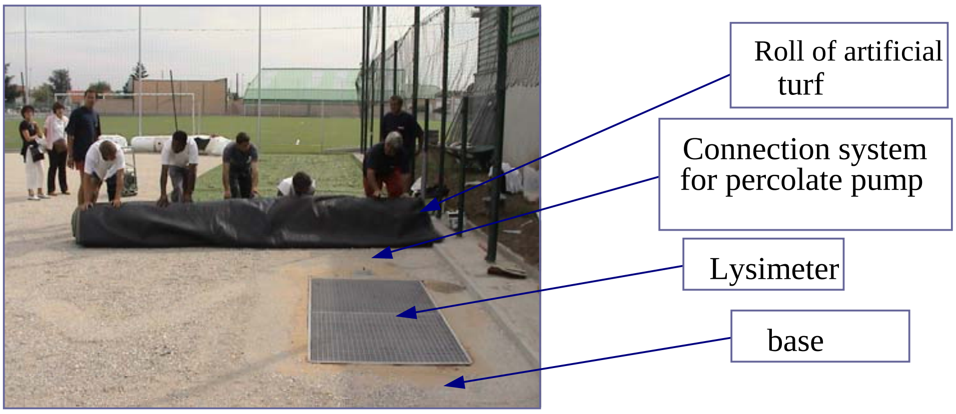


Figure 3: Installation of a roll of artificial fibre turf to cover the lysimetric system.

After full installation of the artificial turf and the filling material (sand and used tyre granulates), the lysimeter is scarcely detectable beneath the playing surface (Figure 4).

Figure 4: Manual filling of the artificial turf situated over the lysimeter with used tyre granulates.

The recovery of the water takes place via a pipe, fixed to a connection orifice located on the base of the lysimeter, which crosses the artificial turf and is then connected to a pump. To take a sample, the pipe is pulled outwards and then after recovery of the water, it is sealed by a cap and pushed back under the turf until the cap is concealed within the granulates (Figure 5).

Figure 5: System for the recovery of the percolates collected in the lysimeter situated under the artificial turf by means of a pipe crossing the artificial turf and connected to a sampling pump.

The monitoring period is **11 months**.

II.3.2. - Experimentation in pilot scenarios

The experimental pilots prepared are made up of rectangular aluminium tanks 2.5 m in length and 1 m in width. The base and sides are made watertight by means of a geomembrane. The tanks are raised to facilitate the collection of the percolates and their base displays a slight inclination towards a low point where the orifice for the emptying and collection of the percolates is located (Figure 6). The supporting floor of the artificial turf is formed by a bed of sand a few centimetres thick which serves as a drain for the percolates, in accordance with what occurs on outdoor pitches.

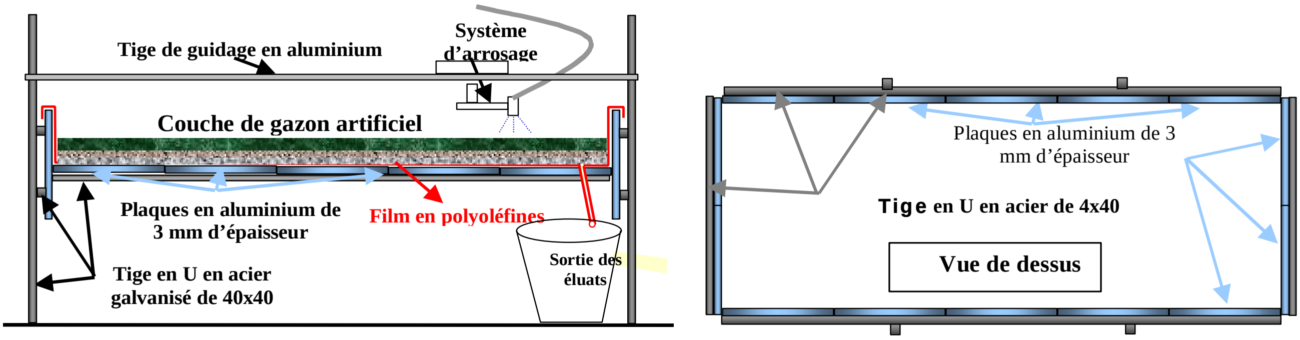


Figure 6 : Cross-section and overhead views of the pilot set-up plan on the EEDEMS experimental platform

The artificial turf mini-pitch is made with 2 rolls of green-coloured fibre separated by a roll of white-coloured fibre (pitch marking lines), all glued with polyurethane glue on the joining strip reserved for this effect. All of the materials correspond to those used on the football field (fibres, granulates of various types, glue) and were supplied to us by FIELDTURF TARKETT.

The implementation of the watering system designed to reproduce the rainfall level consists of a double rack containing 8 dispersion nozzles. The watering rack supplied with drinking water moves back and forth every hour, with 4 of the nozzles watering while going and the other 4 watering while returning, the aim of course being to spread the watering as well as possible. The cycle times and the injection durations are managed by a programmable logic controller. The quantity of water over the entire duration of the experiment has been set in relation to the annual average rainfall levels in the Lyon region, which is 800 mm per year (e.g. Paris: 641 mm; Vienna: 684 mm, Brussels: 833 mm, Budapest: 596 mm, Rome: 828 mm, London: 599 mm, Berlin: 583 mm[10]).

Four pilots (with ETP granulates, virgin EPDM granulates and granulates from PUNR and without filling materials) have been carried out (Figure 7) in a configuration comparable with that encountered on the experimental football pitch site.

As for the football stadium, the analytical monitoring period is **11 months**.

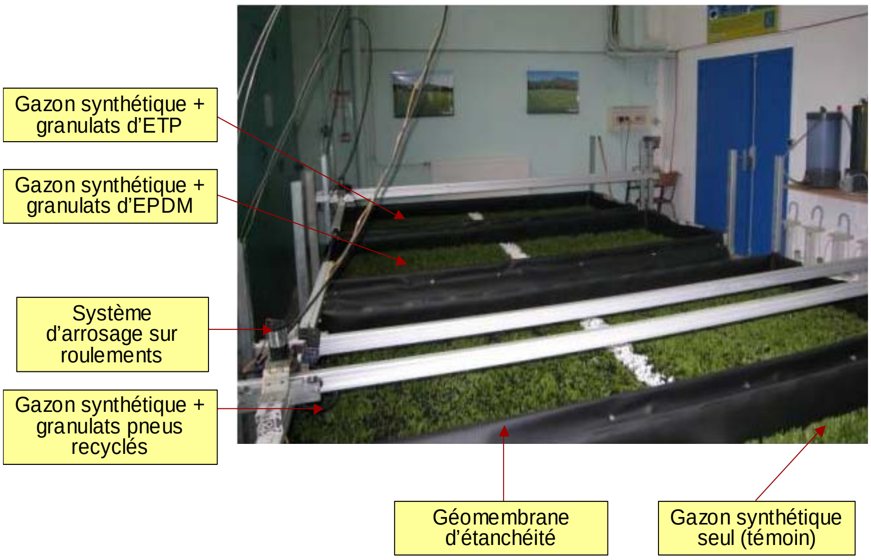


Figure 7: View of the 4 experimental pilots set up on the EEDEMS platform

II.4. - Analytical approaches for evaluation of environmental impact

II.4.1. - Sampling methods

On the four pilots, the percolates are collected each week, stabilised and stored in a cold room. The solutions analysed are reconstituted *pro rata* with the weekly volumes collected according to the volume necessary for the analyses and the period concerned. The analytical schedule is as follows: 7 solutions analysed after 15 days, 1, 2, 3, 6, 9 and 11 months of watering.

[10] http://www.meteo.fr/temps/monde/climats/3-2.htm

On the football pitch, the same number of samples was taken over the period of 11 months but, due to the weather conditions, the analytical schedule was established so as to benefit from a representative volume of periods including the rainy episodes of greater intensity between October 2005 and October 2006.

II.4.2. - Types of analyses carried out and reference systems

The evaluation of the environmental impact of the quality of percolation water is arrived at through physicochemical and ecotoxological analyses.

The elements and chemical substances researched are those entering into the composition of the filling materials, and more particularly those from used tyres. The study has been given this orientation with regard to the debate seen in recent years, and could equally have been aimed at substances of risk entering into the composition of other types of granulates. The exhaustive list comprises 42 physicochemical parameters: total cyanides, phenol index, total hydrocarbons (HCT), 16 polycyclical aromatic hydrocarbons (PAH), total organic carbon (TOC), Al, As, Ba, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se, Sn, Zn, fluorides, nitrates, ammonium, chlorides and sulphates, pH and conductivity.

In order to evaluate possible enrichments of the percolates, the rainwater and supply network drinking water of the pilots was also characterised from a physicochemical perspective.

The evaluation of the impact was established by comparing the concentrations obtained in the percolates to the different French and European guide values currently in force (ICPE[11] discharge standards, acceptability criteria for Discharges of Inert Waste[12], standards concerning the quality of water destined for human consumption[13]). These 3 reference systems were chosen because the percolates' outlets are the natural environment via the infiltrations into the ground and the discharges into the environment via the urban networks. They were also chosen to obtain a minimum of at least one reference guide value for each of the physicochemical parameters. We should specify that the choice of Decree no. 2001-1220 of 20 December 2001 is nevertheless penalising for our study insofar as the percolates would be regarded as a reserve of drinkable water, without taking into account the phenomena of natural decrease in pollutants in the ground or dilution in the water (used and rain) collection networks.

The ecotoxological characterisation of the percolates is arrived at by means of a standardised test to determine the acute toxicity (*Daphnia magna*[14] mobility inhibition test) and a standardised chronic toxicity evaluation test (soft water algae growth inhibition test with *Pseudokirchneriella subcapitata*[15]).

The ecotoxological tests are vital complements to the physicochemical analyses and their interpretation. By putting living beings in contact, either with the materials tested or with water in contact with the materials (leachates, percolates, etc.) and observing the effects produced, it becomes possible to give a reasoned opinion on the potential impact of the substance on the environment. Indeed, the ecotoxological evaluation permits the highlighting of any effects caused by elements or substances not looked for in the chemical analyses, or in the state of traces at concentrations below the detection thresholds but able to display effects by synergy (greater than mere cumulative effects).

A contrario, these standardised tests are means of assessing the conditions under which no ecotoxic risk is run, in both the short and the longer term.

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[11] Ruling on ICPE Discharges (Classified Installations for the Protection of the Environment) of 02/02/98 (art. 32)

12 Decision of the council of 19 December 2002 establishing the criteria and procedures for admission of waste in discharges, in accordance with article 16 and appendix II of Directive 1999/31/CE

[13] Decree no. 2001-1220 of 20 December 2001 and Appendix 13-1 of the Public Health Code (guide values and imperative values for the classification of surface water destined for the production of alimentation water).

[14] Normative reference: NF EN ISO 6341, May 1996 (T90-301)

[15] Normatie reference : NF EN ISO 28692, May 1993

II.5. - Results and comments

II.5.1. - Results on the volumes collected

During the course of 11 months of experimentation, the average volume of percolates collected on each of the 4 experimental pilots was approximately 580 litres of water per m^2. Since the volume of water for each of the 4 pilots is of the order of 800 $l/m^2/15kg$ of granulates, it is proven that approximately 27 to 30% of this volume evaporates naturally in the atmosphere.

On the football pitch, the volumes of percolates collected during the experiment period were low in comparison with the local rainfall level data. For example, the total volume collected in the lysimeter was 86 litres of precipitation per m^2, while the total precipitation recorded in 2006 by the weather station located nearby was 750 mm or 750 litres of water per m^2. During the course of the 11 months of experimentation *in situ*, taking into account an evaporation rate equivalent to that of the 4 pilots, the volume of rain water which percolated through 15 kg of used tyre granulates is estimated at between 525 and 550 litres of water per m^2.

The total volume of percolates collected *in situ* therefore only represents approximately 12% of the volume of the precipitations. This finding can be explained by:

- The evaporation into the atmosphere of a part of the rainwater during rainy episodes of low intensity, the hydraulic charge being too low to permit infiltration;
- The preferential flow of water towards the peripheral outlets due to the calculated number of holes in the backing and the inclines of 1% of the supporting base, parameters ensuring good drainage of the pitch.

On the basis of these results, it is possible to estimate the volumes of percolates, on the one hand infiltrated in the ground beneath a large-size artificial turf pitch and, on the other, directed towards the peripheral drainage system. The estimation shows that for a surface area of 8,000 m^2, the volume of percolates which infiltrates into the supporting ground proves to be inferior to 2 m^3 per day and the volume of percolates directed towards the peripheral drainage system is inferior to 11 m^3 per day (cf. Table 1).

		Flow in m^3/m^2/year				
		Precipitations or watering (1)	Evaporation (2)	Percolates passing through artificial turf (3) = (1)-(2)	Percolates directed to drainage system (4)	Percolates infiltrated in supporting ground (5)=(3)-(4)
Results of experiments for **1 m^2**	Pilots orchestrated	0,800	0,225	0,575	*0*	0,575
	Lysimeter in-situ	0,750	0,225	0,525	0,050	0,085
Estimations for a stadium of **8 000 m^2**	Stadium	6 000	1 800	4 200	400	680
					Equal to 1.86 m^3/jour	Equal to 10.74 m^3/jour

Table 1: Estimation of the flows of percolates infiltrating the ground or directed towards the peripheral drainage network and most often directed towards the waste water collection networks

II.5.2. - Physicochemistry results and report for percolates collected

The pH and conductivity values registered on the percolates from the 4 pilots (7.3 and 8.5; 323 and 637 µS/cm) were generally superior to those recorded on the football pitches (7.1 and 7.85; 72 and 384 µS/cm) but remain without environmental consequences. This finding is explained by the slight difference in chemical composition between the rain water on the one hand and that of the drinking water supply water for the pilots on the other.

Over time and irrespective of the type of filling material, the cyanide, phenol and total hydrocarbon concentrations were very low, most often inferior to the analytical detection limits (cyanide concentration inferior to 60 µg/l, phenol concentration inferior to 20 µg/l and total hydrocarbon concentration inferior to 50 µg/l).

Similarly, the sum of the concentrations of the 6 HAP[16] (Figure 8) proves to be greatly inferior to the guide value from Decree no. 2001-1220 concerning water used for human consumption (1 µg/l).

Graphics Key:

P1 to P7 = No. of samples analysed over 11 months

Control: artificial turf pilot only

PUNR: artificial turf pilot + used tyre granulates

EPDM: artificial turf pilot + EPDM granulates

ETP: artificial turf pilot + ETP granulates

In situ: lysimeter sited on the football pitch

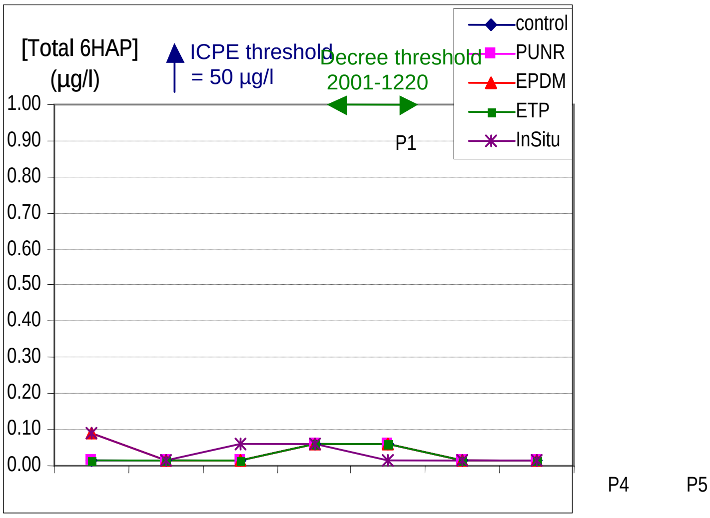

Figure 8: Development of the concentrations of the 6 HAP over time in the 5 experiments in relation to the reference guide values

Overall, the organic composites displayed release kinetics which developed globally in a comparable fashion over time on all of the 5 experiments and in very close concentration ranges that were inferior to the guide values taken as a reference.

The metals Sn, As, Mo and Sb presented slight fluctuations in concentration over time but always at low concentrations and below the reference guide values (ex. Figure 9).

In all the experiments, the metals Al, Ba, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sn and Zn showed a drop in concentrations over time, with a maximum at the level of the two first samples, i.e. on the first month (ex.: Figure 10, Figure 11, Figure 12). The concentrations, already very low at origin, continue to fall to reach values close to those of natural water (rain water and pilot water), below the reference guide values and sometimes even below the analytical detection limits, thereby showing that the essential part of the release of potentially polluting substances takes place in the 1st month after the deployment of the granulates in the artificial turf.

If the Selenium can, for its part, present over time concentrations superior to those of the guide values from Decree no.2001-1220 of 20/12/2001, for the reference control pilot and irrespective of the type of filling granulates, these concentrations are always inferior to the limit value from the Inert Waste Discharge Directive which permits the evaluation of the effects of a source term on the subterranean waters. Due to this fact, the Selenium release rates are regarded as being without impact on the water resources.

16 The 6 HAP concerned by the Decree no. 2001-1220 of 20 December 2001: Benzo(k)fluoranthene, Fluoranthene, Benzo(b)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-cd) pyrene, Benzo(g,h,i)perylene.

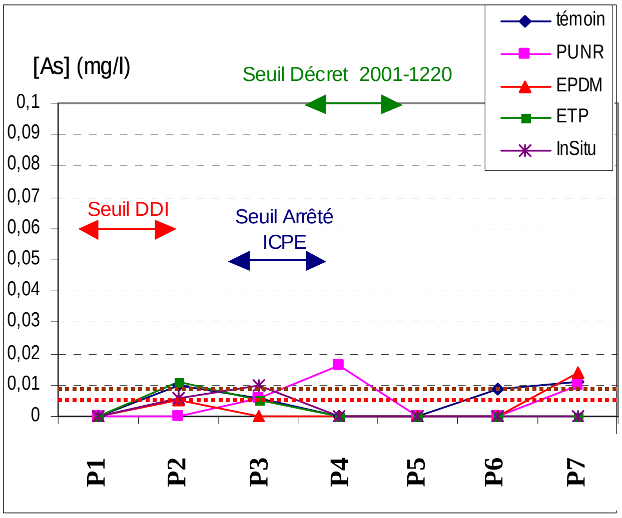

Figure 9: Development of As concentrations over time in the 5 experiments compared to the reference guide values (the red dotted straight line corresponds to the average contents of the pilot supply water and the rain water)

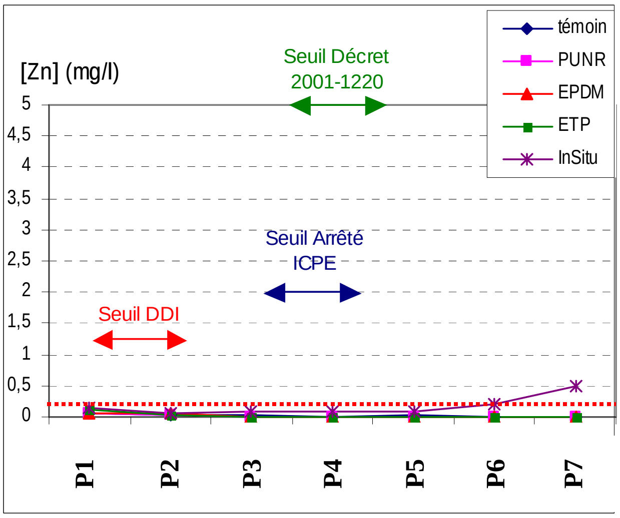

Figure 10: Development of Zn concentrations over time in the 5 experiments compared to the reference guide values (the red dotted straight line corresponds to the average contents of the pilot supply water and the rain water)

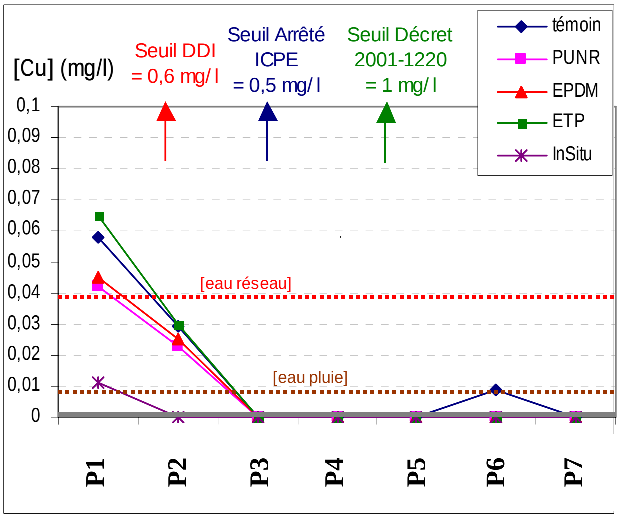

Figure 11: Development of Cu concentrations over time in the 5 experiments compared to the reference guide values (in grey: analytical detection limit)

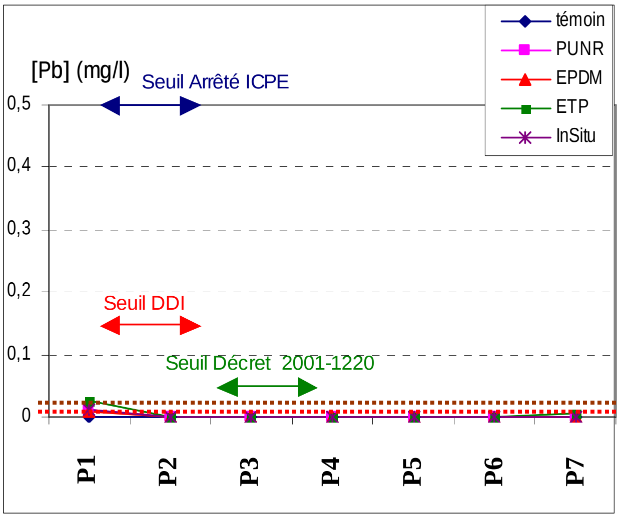

Figure 12: Development of Pb concentrations over time in the 5 experiments compared to the reference guide values (the red dotted straight line corresponds to the average content of the pilot supply water, while the brown dotted line corresponds to the average content of the rain water

Concerning the anions, despite a value for the sulphates very slightly greater than the reference guide value (Decree no. 2001-1220 of 20/12/2001) at the start of experimentation on the pilot containing the used tyre granulates (1st sampling), the results obtained show low concentrations in the percolates on the 4 pilots but particularly *in situ* (ex. Figure 13 and Figure 14).

The same goes for NH_4^+ on the first month of pilot experimentation.

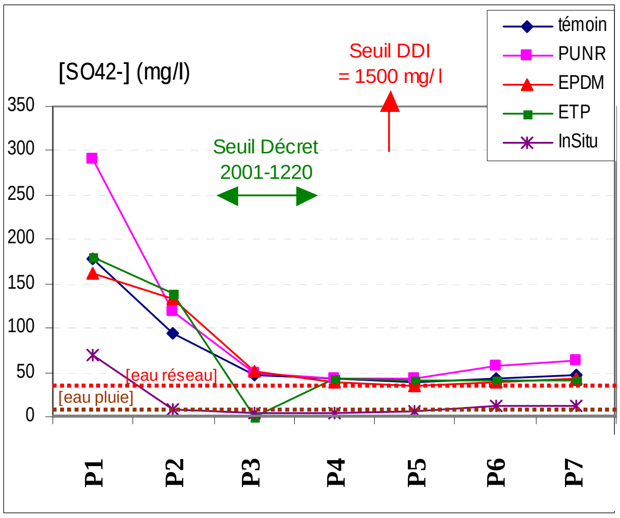

Figure 13: Development of Sulphate concentrations over time in the 5 experiments compared to the reference guide values

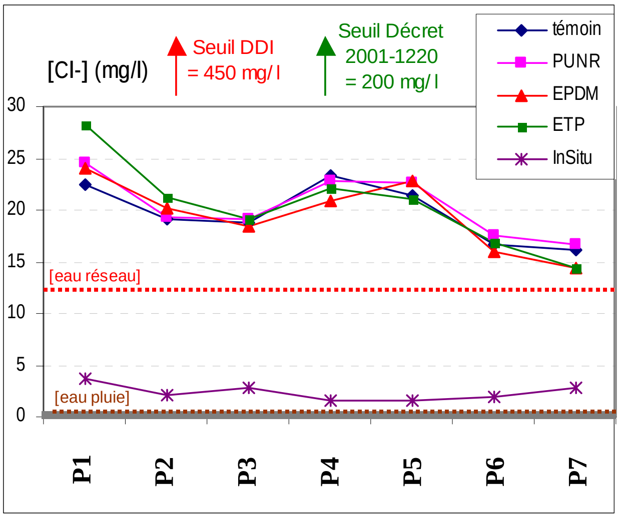

Figure 14: Development of Chloride concentrations over time in the 5 experiments compared to the reference guide values

II.5.3. - Conclusions

All of the results obtained on the percolates from the 3 pilots containing the granulates lead to the observation of a release kinetic comparable over time, with none of the 3 granulates distinguishing itself from the others and pilot no. 1 in artificial turf only taken as control itself displaying release rates fairly close to those of the 3 pilots containing the different granulates. The concentrations recorded are low for the majority of the components and elements researched. Certain elements present slightly stronger concentrations at the start of experimentation, which then fall very rapidly, thereby indicating a very rapid decrease in release rates.

In situ on the football pitch, the concentrations and release kinetic observed are fairly comparable. It is interesting to note that the elements such as the chlorides, fluorides and sulphates are in lower concentrations than in the percolates collected on the pilots, this finding being connected with a difference in chemical composition of the water which percolates through the sports surface (rain water on the site and drinking water supply network water for the 4 pilots).

This analytical approach in the pilot scenarios as *in situ*, based on a comparison with the currently applicable French and European guide values, shows that the concentrations of organic composites, metals and anions of the percolates are compatible with the water resource quality requirements.

II.5.4. -

Ecotoxological study results and report

For the football pitch (Table 2), the tests carried out on the samples (after 3; 3.5; 6 and 7.5 months) did not show toxicity for the daphnies or for the algae, except for the latter in the final sample at 7.5 months. The CE50[17] is in this case just reached (low impact), a fact which, with regard to the results of the chemical analyses and the results of these same tests on the percolates from the pilots, appears to be an artefact linked to the immediate environment of the pitch (external pollution).

Lysimeter on the football pitch		**To+3 months**	**T+3.5 months**	**T+6 months**	**T+7.5 months**
Sampling date		2-Jan.-06	19-Jan.-06	4-Apr.-06	30-May-06
Daphnia magna	CE50 24h (UT)	< 1	< 1	<1	<1
P. subcapitata	CE50 72h (UT)	Not performed vol. insufficient	<1.2	<1.2	1.4
	inhibition at 80%		7.5%	1.6%	57.5%

Table 2: Results of the ecotoxological tests on the percolates collected in the lysimeter positioned on the football pitch (Note: UT = 100 / CE50)

Essentially, the results of the physicochemical analyses of the percolates from the 4 pilots on the EEDEMS platform and collected 15 days after their launch show that these percolates are the most heavily charged. However, the ecotoxological tests performed on these same percolates show a very slight toxicity as regards both the daphnies and algae. For these two organisms, the CE50 was never reached. Subsequently, none of the samples (after 3 and 8 months) showed toxicity for these two organisms (Table 3).

		Pilots			
Sampling of 15-Nov-05		**Control T+15d**	**Used tyres T+15d**	**EPDM T+15d**	**ETP T+15d**
Daphnia magna	CE50 24h (UT)	<1	<1	<1	<1
	inhibition at 90%	25%	15%	30%	0%
P. subcapitata	CE50 72h (UT)	< 1,2	<1,2	<1,2	<1,2
	inhibition at 80%	10.3%	15.0%	33.3%	14.9%
Sampling of 30-Jan-06		**Control T+3 months**	**Used tyres T+3 months**	**EPDM T+3 months**	**ETP T+3 months**
Daphnia magna	CE50 24h (UT)	<1	<1	<1	<1
	inhibition at 90%	0%	0%	0%	0%
P. subcapitata	CE50 72h (UT)	< 1.2	<1.2	<1.2	<1.2
	inhibition at 80%	0.0%	0.0%	0.0%	0.0%
Sampling of 15-05-06		**Control T+ 8 months**	**Used tyres T+ 8 months**	**EPDM T+ 8 months**	**ETP T+ 8 months**
Daphnia magna	CE50 24h (UT)	<1	<1	<1	<1
	inhibition at 90%	0%	5%	0%	0%
P. subcapitata	CE50 72h (UT)	< 1.2	<1.2	<1.2	<1.2
	inhibition at 80%	0.4%	0.0%	1.0%	0.0%

Table 3: Results of the ecotoxological tests on the percolates collected on the 4 pilots set up on the EEDEMS platform (Note: UT = 100 / CE50)

[17] The CE50 is the effective concentration of percolates that leads to the immobilisation of 50% of a batch of daphnies subjected to the test for an exposure period of 24 hours.
The CE50 is the effective concentration of percolates which leads to 50% inhibition of the growth of a population of algae in relation to a control without percolates after an exposure period of 72 hours.

The placing in pilot scenarios in a room with a controlled atmosphere and supervised human intervention consequently permits the avoidance of the external vagaries inherent to an outdoor football pitch (pollution from various sources: weeding in the neighbourhood, urine, etc.) likely to have even very slight repercussions on the quality of the percolates vis-à-vis certain organisms.

II.5.5. - Conclusions

From an ecotoxological point of view, the nature of the percolates having passed through a 3rd-generation artificial pitch are proven to be without impact on the environment, irrespective of the type of filling granulates.

III. Evaluation of the health risks linked to gaseous emissions

III.1. - Characterisation of the VOC and formaldehyde emissions by artificial turf sports surfaces

The characterisation and measurement of the volatile organic compound (VOC) and aldehyde (including formaldehyde) emissions by the sports surfaces considered during the environmental impact evaluation study (previous §) was performed by the Centre Scientifique et Technique du Bâtiment (CSTB[18]), with the aid of the emission method test rooms used for the characterisation of chemical emissions in indoor air of construction products.

III.1.1. - Materials used

As for the experiments relating to the environmental evaluation, the different materials tested are: an artificial turf with green artificial fibres including a band of white artificial fibres; polyurethane glue; sand; elastomer granulates of 3 different types.

The proportions of the different constituents (stored in watertight bags until the experiment) are still 17.5 kg of sand and 15 kg of granulates per m^2, which for samples of 0.15 m^2, equals 2.625 kg of sand and 2.25 kg of granulates.

III.1.2. - Methodology

Each test sample is prepared by installing the artificial turf in a stainless steel box (Figure 15), adding a thickness of approximately 1 cm of sand (Figure 2) then approximately 4-5 cm of elastomer granulates. The test sample prepared in this way is then placed in the emission test chamber.

For the 4 tests performed at 23 ± 2°C, the samples were prepared in stainless steel tanks of a dimension of 0.78 m x 0.19 m. The effective emission surface of these test samples was 0.15 m^2.

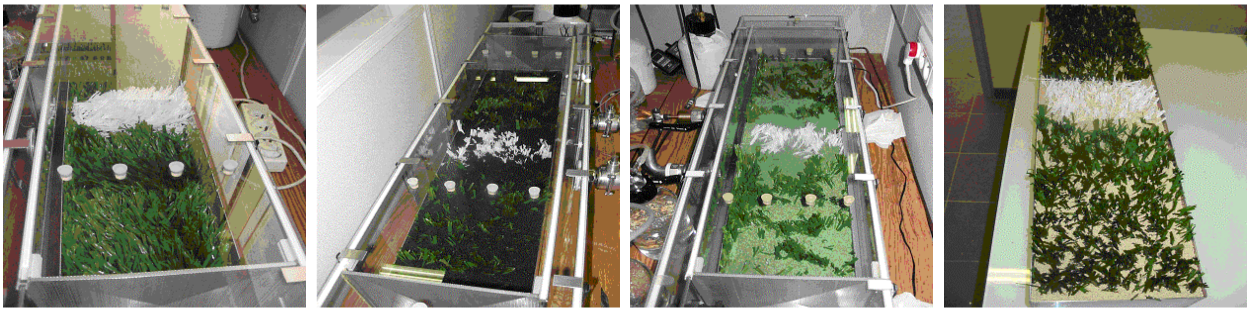

Figure 15: Test samples. From lest to right: artificial turf only; artificial turf with ballast sand and used tyre granulates; artificial turf with ballast sand and EPDM granulates; artificial turf with ballast sand and ETP granulates

[18]Centre scientifique et technique du bâtiment *(scientific and technical building centre)*: a public establishment of an industrial and commercial nature under the supervision of the minister for Housing, Directorate of Town Planning, the Environment and Construction

III.1.3. - Analytical conditions

Each of the test samples prepared was placed in an emission test chamber under controlled conditions of temperature (23 ± 2 °C) and relative humidity (50 ± 5 %), as per the recommendations of the standard project taken as a reference: prEN IS0 16000-9: *Indoor air – Part 9: Determination of the emission of volatile organic compounds from building products and furnishing – Emission test chamber method* (ISO, 2005).

The 5 tests were performed in accordance with a so-called "ground" emission scenario (specific ventilation rate: q = 1.25 $m^3.m^{-2}.h^{-1}$). The samples of VOC and aldehydes by pumping on special adsorbent support were performed in duplicate before the start of the test (**D0**) then after 24 ± 2 hours (**D1**), 72 ± 2 hours (**D3**) and 28 ± 2 days (**D28**) of conditioning of the sample in an emission chamber.

The samples and analyses of the VOC were performed as per the recommendations of the NF IS0 16000-6 standard: *Indoor air – Part 6: Dosage of volatile organic compounds in the indoor air of premises and test enclosures by active sampling on the sorbant Tenax TA, thermal desorption and chromatography in gaseous phase using MS/FID* (AFNOR, 2005).

The samples and analyses of the aldehydes were performed as per the recommendations of the NF ISO 16000-3 standard: *Indoor air – Part 3: Dosage of formaldehyde and other carbonylated compounds – Method by active sampling* (AFNOR, 2002).

III.1.4. - Results

The experiments conducted with the aid of emission chambers used for the characterisation of chemical emissions in indoor air of construction products permitted the identification of 112 substances (cf. table 4 in appendices).

The emission kinetic represented by Figure 16 shows that the concentration of Total VOC (TVOC) decreased very rapidly in the 4 samples. The fall is significant between D1 and D3. Between D3 and D28, the curve displays a lower incline and at end of testing on D28, the samples containing the used tyre and EDP granulates display comparable concentrations, slightly greater than that of the turf only, while those from the sample with the EPDM granulates are still relatively high.

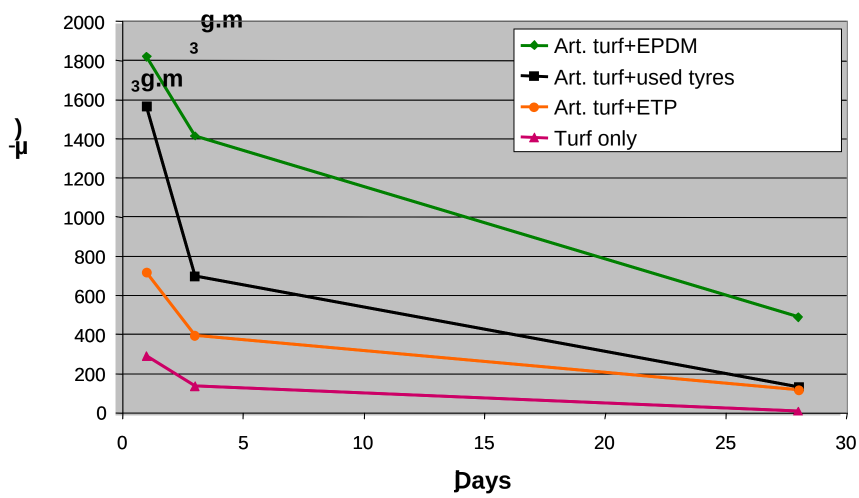

Figure 16: Comparison of the Total VOC concentrations issued between D1 and D28 by the 4 samples

The concentrations of VOC and aldehydes obtained correspond to the arithmetical average of the 2 samples taken and analysed, corrected from the chamber blank value measured at D0. These concentrations are the exposure concentrations for the product tested in its emission scenario.

The approach adopted permits a direct comparison of the VOC and formaldehyde emissions of the different elastomer granulate-based sports playing surface, under controlled conditions of temperature, relative humidity and air renewal.

The results of the tests were also expressed in specific emission factor form (SER_a in µg.m^{-2}.h^{-1}), calculated according to the following formula (as per prEN ISO 16000-9) : $\mathbf{SER_a = C \cdot q}$

Where **C** represents the individual VOC (or TVOC) concentration in time t (in µg.m^{-3}) and **q** the specific ventilation rate of the test (q = 1.25 m^3.m^{-2}.h^{-1} for the "ground" scenario).

III.1.5. - Conclusions

The emissions of VOC and formaldehydes by elastomer granulate-based sports playing surfaces was characterised with the aid of the standards applicable to the characterisation of emissions in indoor air of construction products (prEN ISO 16000-9, NF ISO 16000-6 and NF ISO 16000-3) and permitted the highlighting of the emission of 112 substances. It emerges from this that:

1 – The emissions from the artificial turf only are very low (TVOC = 8.3 µg.m^{-3} at 28 days) compared with those from other construction products (ex: parquet flooring);

2 – The emissions from the artificial turf containing used tyre granulates are relatively low (TVOC = 134 µg.m^{-3} at 28 days).

3 – The issues from the artificial turf containing ETP granulates are also relatively low (TVOC = 118 µg.m^{-3} at 28 days). The compounds identified in the emission are overall comparable with those identified in the used tyre granulate emissions.

4 – The emissions from the artificial turf containing EPDM granulates are greater (TVOC = 490 µg.m^{-3} at 28 days).

III.2. - Study of the Health Risk Evaluation (HRE)

A HRE was performed by INERIS[19], in order to evaluate more precisely in indoor situation the health risks linked to the inhalation of the substances identified (112 substances) as per the reference protocol implemented by the CSTB (cf. previous §).

This evaluation and its conclusions only concern the inhalation of the VOC and aldehydes of which the emissions have been quantified by the CSTB. The possible heath risks associated with the emissions of other substances in normal situations or due to ageing or accidental damage of the surfaces were not evaluated.

This type of study meets a strong current demand for the improvement of knowledge concerning emissions of chemical substances by construction materials and the characterisation of the associated health and environmental effects. On a European scale, within the framework of the European Directive "Construction products" (89/106/EEC), essential requirement no.3, "Hygiene, health and environment", addresses the characterisation of emissions of gaseous, particulate or radioactive substances from products placed on the community market. Due to the lack of harmonised methods at European level permitting the evaluation of these characteristics, this requirement is currently scarcely taken into account. Work aimed at harmonising these methods was launched in 2003 under the aegis of the European Commission. An inventory of the national systems for the determination of emissions from materials in indoor air was carried out and published in December 2005 [EU, 2005]. The protocol implemented for the characterisation of the gaseous emissions (previous §), on the results of which this evaluation of health risks is based, belongs to the list of reference protocols.

In France, the Plan National Santé Environnement (PNSE – *national plan for health & the environment)*) announced in June 2004 by the ministries of health, ecology, employment and research, set 45 actions, 12 of them priorities. Among the latter, action 15 aims to "put in place a labelling of the health and environmental characteristics of construction materials." The target set by the PNSE is a labelling rate of 50% to be reached by 2010. This evaluation of the health risks and the characterisation study of the emissions on which it is based therefore fit into a framework that fully meets current health requirements.

[19] Institut National de l'environnement industriel et des risques : Établissement Public à caractère Industriel et Commercial placé sous la tutelle du ministère de l'Ecologie et du Développement durable

The evaluation of the health risks corresponds to a rigorous scientific initiative put forward during the 1980s by the American National Research Council. In Europe, it constitutes the benchmark tool for evaluations of the health and environmental risks of chemical substances. Formalised in methodological guides (*Technical Guidance Document* of the European Commission, INERIS guide for classified installations [INERIS, 2003-a], for example.), it unfolds as per the following stages: 1) inventory of substances; 2) identification of the danger and research into dose-response relationships; 3) evaluation of exposures, then quantification of the health risks.

III.2.1. - Exposure scenarios

The artificial turf sports surfaces studied are almost exclusively used outdoors. Nevertheless, some usages can be encountered in closed gymnasia, generally of a large size. The exposure levels of persons (athletes and spectators) are then higher in the absence of atmospheric dispersion permitted by the wind and photochemical degradation of the compounds emitted, phenomena occurring *a contrario* outdoors.

The results of the French “Listing of Sporting Equipment” (LSE), constructed before 31 December 2005, have been available since July 2006. It confirms the highly heterogeneous character of the dimensions of these infrastructures. Consequently, in this study, it is impossible to take as a basis types of gymnasia representative of the French reality.

By virtue of the principle of prudence (these exposure situations being rare but still likely to have taken place), this evaluation of the health risks is limited to an unfavourable situation in terms of exposure, namely **indoor usage,** in closed gymnasia. It fits well into a context of first-level approach of the HRE where the most extreme situations are envisaged (worst-case scenario).

Moreover, the evaluation of exposure outdoors appears more complex. Study models for the atmospheric dispersion of gaseous or particulate compounds emitted by a surface exist, but they only permit the modelling of the concentrations in the air within a radius of 100 m to 10 km around the emitting surface. Their implementation in the present context would not permit the evaluation of the exposure of persons who train on the sporting surface. This constitutes an additional element that prompted the conducting of a study in an indoor scenario. The conclusions of the study, peculiar to this usage in an indoor scenario, shall be put into the perspective of general usage on outdoor sports surfaces.

For reasons of feasibility and by virtue of the principle of prudence in the first-level approach of the HRE, an unfavourable situation in a gymnasium has been chosen, rather than exposure on an open-air playing surface. The choice was therefore made of a worst-case situation by considering a gymnasium of the smallest size possible (in this way, the substances emitted will be less diluted in the volume of air). Among the different categories from the INSEE inventory of 1988, the smallest gymnasia (category A) have a surface area of 230 m^2. Moreover, the French Ministry of Youth and Sports has set minimum free heights above the floor: the lowest height is 7 m. Furthermore, two indoor structures constructed in 2006 (source: FIELDTURF TARKETT) with 3rd-generation artificial turf, have a surface area of 2,500 m^2, 1,800 m^2 of which is covered by artificial floor with an average under-ceiling height of 8 m. Insofar as a study conducted in 13 Parisian gymnasia produced one hall with a height of 6 m (the smallest gymnasium having a volume of 3,600 m^3), this value was chosen as the lowest height possible.

The standard gymnasium chosen in this study therefore has a surface area of 230 m^2 and a height of 6 m, giving a volume of 1,380 m^3. The air renewal rate chosen is 0.5 vol.h^1.

The choice was also made to consider all of the substances for which emission data is available and not to exclude any *a priori*. Only the chemical health risks were taken into consideration, as the biological, physical or radiological risks were not concerned in the present context.

The emission factors, determined by the characterisation study in § III.1.4, permitted the modelling of the interior concentrations in the gymnasium for each of the types of granulate associated with artificial turf and for artificial turf only. In parallel to this, the dangers by inhalation and the reference toxicological values (RTV) of all of the VOC and aldehydes measured, that is 112 substances (cf. Table 5 in appendix), were searched for in the reference international toxicological databases. For 16 compounds with an RTV (in bold in table 5 in the appendices), the quantitative evaluation of exposure levels and of the associate health risks was carried out.

Uncertainties exist concerning the dangers of the substances studied: uncertainties in the toxicological data and the RTV proposed (possible exacerbation or inhibition of toxicity in the case of mixing of pollutants emitted by the artificial surfaces, possible products of transformation of the pollutants emitted, reactions in heterogeneous phase by adsorption on the materials present in the building). These are inherent to any evaluation of the health risks according to current scientific knowledge and practice and cannot be quantified.

Acute and chronic exposure scenarios were developed for 4 population groups:

- the workers responsible for installing the surfaces. In a gymnasium, the installation of an artificial floor takes 10 days, devoted to the profiling of the ground, the laying of the mat and the installation of the sports surface with the granulates, which last 3 days (source: FIELDTURF TARKETT),
- the professional athletes and coaches present in the gymnasium throughout the day,
- the amateur athletes training regularly in the gymnasium. A fairly severe scenario was envisaged whereby the dedicated athlete trains twice during the week and once at the weekend (training of a duration of 2 hours). Moreover, it was considered that he would take part in an amateur competition at weekends (4 hours' presence in the gymnasium),
- the spectators at sporting events, attending the gymnasium regularly, namely every weekend (2 hours' presence in the gymnasium each time).

Each of these population groups may be exposed (Table 4):

- <u>in an acute fashion</u> when a new floor has just been laid. For the workers, the results of the measurements at D1 were used, while for the general public, who are presumably not authorised to enter the gymnasium on the very day of the new floor's laying, the measurements at D3 were used;
- <u>in a chronic fashion</u>, since it was considered that the exposure is repeated throughout the year. The workers are permanently exposed to the concentrations emitted during installation, so the concentrations measured at D1 are used. For the general public, the chronic exposure (the most frequent in addition) is calculated on the basis of the surface's emissions measured at D28. In the absence of measurement of the emissions some months after the laying of the floor, it was considered that the measurement at 28 days (D28) is representative of the residual emissions for the remainder of the surface's lifespan.

<table>
<tr><th></th><th>Acute exposure</th><th>Chronic exposure</th></tr>
<tr><td>Workers laying artificial turf</td><td>At time of laying of artificial turf
➔ emissions at D1</td><td>8h per day, 71 days per year (1)
$f_{workers} = 0.07$
➔ emissions at D1</td></tr>
<tr><td>Professional athletes and coaches</td><td rowspan="3">At the opening of the gymnasium after the laying of new floor
➔ emissions at D3</td><td>8h per day, 365 days per year (2)
$f_{athletes} = 0.33$
➔ emissions à J28</td></tr>
<tr><td>Amateur athletes</td><td>10 h per week, 44 weeks per year (3)
$f_{amateurs} = 0.05$
➔ emissions at D28</td></tr>
<tr><td>Spectators</td><td>Dedicated spectator present at all the compétions (4)
$f_{spectators} = 0.009$
➔ emissions at D28</td></tr>
</table>

Table 4: Overview of exposure scenarios studied for chosen population groups

Key: f = fraction of annual time spent in gymnasium

Notes: (1) It was considered that 236 days are worked annually, corresponding to 365 days from which were subtracted the 2 days of the 52 weekends and the 5 x 5 days of paid leave. Given that, for the laying of a surface that takes 10 days, 3 days are devoted to the laying of the sporting surface containing the granulates, the annual exposure duration is 71 days (71 = 236 × 3/10).

(2) It was considered that a top-level athlete would train every day.

(3) It was considered that training and competitions take place throughout the year except during the 8 weeks of the months of July and August.

(4) 40 competitions per year were envisaged.

As the calculation of the concentration inhaled does not involve physiological parameters, the results obtained apply equally to exposure by inhalation of an adult as of a child.

The concentrations inhaled were calculated so as to permit *in fine* the calculation of the risk indices (for the health effects with a threshold) and of the individual risk (for the effects without threshold, carcinogenic effects).

The non-carcinogenic effects are those for which an effect threshold exists (deterministic phenomenon). The US-EPA expresses this mechanism by a reference dose (RfD) or concentration (RfC) (for ingestion or inhalation respectively). These references doses are determined on the basis of the Doses Without Noxious Effect (DSENO or NOAEL) or Minimum Doses resulting in the Observation of a Noxious Effect (DMENO or LOAEL), divided by the safety factors (factor 10 taking account of the inter-species variability, factor taking account of the existence of sensitive persons, etc.).

The carcinogenic effects are those for which the relationship between the exposure and the appearance of the effect is without threshold (probabilistic phenomenon). The US-EPA expresses this mechanism by an excess of unitary risk (EUR) corresponding to the excess risk for an individual exposed throughout his life to a dose unit (inhalation of 1 µg/m^3 or ingestion of 1 mg/kg/j). For example, an EUR_i of 6.10^{-6} (µg/m^3)$^{-1}$ (case of benzene) signifies that an exposure of 1 million persons during 70 years to a concentration of 1 µg/m^3 of benzene is likely to result in 6 additional cases of leukaemia during the same period (compared with a non-exposed population of the same size).

The evaluation of the health risks was performed for a normal use of the artificial turf sports surfaces, namely in the absence of taking into account of the ageing of the surface or their accidental damage and any associated emissions.

The standard gymnasium chosen having a surface area of 230 m^2, denoted as S, and a height of 6 m, giving a volume of 1,380 m^3, denoted as V, the parameters chosen for the modelling of the concentration in the gymnasium were as follows:

- the entire surface area of the gymnasium was covered with artificial floor made either from granulates or not from granulates. The emitting surface was therefore equal to the surface of the gymnasium, which in this case was 230 m^2;
- the emissions from the artificial floor are spread uniformly throughout the volume of the gymnasium's air; in other words, the interior concentrations in the gymnasium are homogeneous;
- the air renewal rate in the gymnasium was average, or even mediocre. This rate was set at 0.5 volume/hour, as the literature did not provide data regarding the ventilation in the gymnasia. This rate (denoted asτ) was regarded as constant throughout the day, whether the gymnasium was empty or occupied.

The calculation of the concentrations in the gymnasium was made according to the equation (1):

$$\mathbf{C_{gymnasium} = (SER_{JX} \times S) / (\tau \times V)}$$

With:

- SER_{JX}, the specific emission factor established during the characterisation of the emissions (in µg.m^{-2}.h^{-1}). According to the scenarios chosen, this factor is that measured at D1, D3 or D28. The SER_{JX} at the detection threshold are taken as equal to this threshold.
- τ, the gymnasium's air renewal rate (h^{-1})
- S and V, respectively the surface area of the artificial floor, taken as equal to the surface area of the gymnasium (m^2) and the volume of the gymnasium (m^3)

The calculation of the concentrations inhaled was made:

- Within a context of acute exposure, with the concentration inhaled being taken as equal to the gymnasium's interior concentration, calculated as per the equation (1) with the emissions measured at D1 (workers installing the floor) or D3 (other population groups).
- For chronic exposure, the concentration inhaled (CI) is calculated according to the equation (2):

$$\mathbf{CI = C\ gymnasium \times f}$$

With:

- C gymnasium, the interior concentration in the gymnasium calculated as per the equation (1) with the emissions measured at D1 (workers installing the floor) or D28 (other population groups).
- f = fraction of annual time spent in the gymnasium

- The quantification of the health risks is evaluated for the effects with thresholds and for the effects without thresholds.

The characterisation of the risk for toxics with <u>threshold effects</u> by inhalation (acute or chronic exposure) is expressed by a risk index (IR) as per the equation (3): $IR = \frac{CI}{VTR}$

With:

- CI, the Concentration Inhaled (µg/m^3)
- RTV, the Reference Toxicological Value (µg/m^3)

The IR is calculated for each of the health risk tracers. The benchmark for the assessment of the health risk is set at 1. When the IR is inferior to the value of 1, the risk is regarded to be of no cause for concern within the current status of knowledge.

In the first HRE approach [INERIS, 2003-a], the sum of the IR is also calculated. However, strictly speaking, it can only provided an indication on the combined effects of the risks if the respective effects of each of the substances contributing to the risk concern the same target organ.

- The characterisation of the risk linked to an exposure to carcinogens (<u>effects without thresholds</u>) is expressed by an excess of individual risk (EIR).

This EIR represents the probability of the individual developing the effect associated with the substance during his life due to the exposure concerned.

$$\mathbf{ERIinh = CI \times ERUi \times T / Tm} \quad \text{equation (4)}$$

With:

- ERIinh, the Excess Individual Risk by inhalation
- CI, the Concentration Inhaled (µg/m^3)
- ERUi: Excess of Unitary Risk by inhalation ((µg/m^3)$^{-1}$)
- T: duration of exposure (years)
- Tm: period of time over which the exposure is averaged (70 years according to convention)

The benchmark for the assessment of the health risk is set at 10^{-5}. When the EIR is inferior to the value of 10^{-5}, the carcinogenic risk is generally regarded as acceptable according to current knowledge.

The excess of global risk of cancer (all cancer types) can be estimated by adding the EIR associated with each carcinogenic substance.

The results described in the next section correspond to a modelling which fits in well to a context of first-level HRE approach where the most extreme situations are envisaged (worst-case scenario), that is to say a small, poorly ventilated gymnasium and without taking into account the ventilation rate of individuals.

In order to be positioned as close as possible to the real usage conditions on the basis of the results acquired, the INERIS has also carried out sensitivity tests on:

- The dimension of the gymnasium: by considering a realistic situation (emitting surface of 1,800 m^2 and gymnasium volume of 20,000 m^3; the air renewal rate remaining unchanged),

- The average air renewal rate chosen for the HRE was set at 0.5 vol.h^{-1}. A study conducted in a French gymnasium [Air Normand, 2000] showed an average air renewal rate of between 0.54 vol.h^{-1} in summer and 1.2 vol.h^{-1} in the winter period. This confirms that the context for the calculation of the interior concentrations in the gymnasium and for the concentrations inhaled resulting from this is *a priori* fairly significant. The ventilation is a parameter that has a significant effect on the results.

- The ventilation rates of individuals (male and female) were not taken into account. A sensitivity test was conducted on the professional athletes group. This test shows that if an approach is chosen that takes account of respiratory rates, the risk indices turn out to be higher but the conclusions of the study are nevertheless not modified.

III.2.2. - Results and recommendations

The interior concentrations modelled in the standard gymnasium chosen (volume of 1,380 m^3) were compared to the average ubiquitous concentrations in the ambient exterior and interior air in France. This placing in perspective indicates that, for the 9 VOC and aldehydes concerned and on the basis of the results acquired during the characterisation of the emissions, the maximum concentrations in the gymnasium, modelled at D28, are of approximately the same magnitude as the ubiquitous concentrations in the ambient air (exterior and interior), or even inferior in certain cases.

The results of the INERIS HRE based on the concentration of the substances identified and on the previous hypotheses (worst-case scenarios) indicate that, according to current knowledge and on the basis of the information transmitted by the manufacturers (regarding exposure levels of workers responsible for installation in particular), the VOC and aldehyde emissions from the three types of artificial floors studied in indoor situation (small and poorly ventilated gymnasia) are of no cause for concern for human health, for the workers installing the surfaces as well as for the general public, professional or amateur athletes, adults and children, with the exception of the case of workers installing artificial surfaces in small and poorly ventilated gymnasia who are exposed for over 5 years. In this case, it is recommended that during installation, an air renewal rate of *at least* 2 vol.h^{-1} is assured.

This type of recommendation corresponds to that of the Observatoire français de la Qualité de l'Air Intérieur (OQAI), which recommends to private individuals several days' ventilation of rooms of a building which have just been constructed or renovated or after the installation of new furniture or decoration (page 5 of the "Les bons gestes pour un bon air" *(good moves for good air)* guide.

Concerning ventilation, moreover, it is appropriate to refer to the minimum fresh air intake rates imposed in France by the departmental health regulation (RSD) required irrespective of the ventilation system (these are the only regulatory provisions currently in force in terms of building ventilation). The INERIS recommends that this air renewal rate is maintained outside competitions, from the moment that professional or amateur athletes train on this type of indoor surface.

In conclusion to its study, the INERIS stipulates that the health risks associated with the inhalation of VOC and aldehydes emitted by artificial surfaces on pitches in outdoor situations give no actual cause for concern as regards human health.

IV. General conclusions

Evaluation of the environmental impact on water:

The analytical approaches as regards the environmental evaluation of water passing through artificial turf were conducted over a period of one year: on the one hand, by orchestrating representative pilots on the EEDEMS environmental platform (three types of filling granulates tested: TPE, EPDM, granulates recycled from used tyres) and on the other, *in situ* on a football pitch (recycled PUNR granulates). At the end of the experiments, the results showed that:

1 – All of the physicochemical results (42 parameters analysed) obtained on the percolates from the 3 2.5-m^2 pilots leads to the observation of a release kinetic for potentially polluting substances comparable to the course of time irrespective of the type of granulate used (7 percolate samples analysed at one year). The artificial turf pilot without filling granulates used as a control also displayed release rates fairly close to those of the 3 pilots. The concentrations recorded were low for the majority of the compounds and elements searched for. While certain elements displayed slightly higher concentrations at the start of experimentation, these fell very rapidly, thereby indicating a very rapid reduction effect in terms of release rates.

2 - *In situ* on the football pitch orchestrated in the Lyon region (France), the concentrations and release kinetics are fairly comparable to those observed on the pilots. The chlorides, fluorides and sulphates are even in lower concentrations than in the percolates collected on the pilots, a finding to be linked with the difference in chemical composition of the water that has percolated through the sports surfaces (rain water *in situ* and drinking water on the pilots).

3 – On the basis of a comparison with the French and European limit values currently in force, the concentrations of organic compounds, metals and anions from the percolates are without impact on water resources.

4 – From an ecotoxicological viewpoint, the results obtained show that the nature of the percolates likely to infiltrate into the ground underlying the artificial turf sports surface proves to be without impact on the aquatic environment in the short and medium term (standardised tests carried out on the first percolates and repeated several times during the year).

According to current research, after a year’s experimentation, the results on the 42 physicochemical parameters identified and on the ecotoxocological tests show that water passing through artificial turf using as filling either virgin TPE or EPDM or granulates resulting from the recycling of PUNR are not likely to affect water resources in the short and medium term.

Evaluation of the health risks linked to gaseous emissions

The characterisation of the emissions of Volatile Organic Compounds and aldehydes by elastomer granulate-based sports surfaces has been conducted by the CSTB (Centre Scientifique et Technique du Bâtiment - France) using the standards in force for the characterisation of the emissions in indoor air of construction products (emission chamber). The results show that:

1 – Emissions from the artificial turf only (control with no granulate filling) are very low in relation to those from other construction products;
2 - Emissions from the artificial turf containing used tyre granulates are relatively low;
3 - Emissions from the artificial turf containing ETP granulates are also relatively low. The compounds identified as being emitted is comparable overall to those identified in the used tyre granulate emissions;
4 - Emissions from the artificial turf containing the EPDM granulates are the most significant.

A Health Risk Evaluation (HRE) was conducted by the Institut National de l'Environnement Industriel et des Risques (France). This HRE was based on the values of the concentrations of 112 substances identified in the emission chambers and their comparison to the international toxicological reference values (RTV). According to the HRE methodology, a “worst-case scenario” was modelled (small, 1,380-m^3 gymnasium (6 m x 230 m^2) and poorly ventilated (0.5 vol.h^{-1})) taking into account four population groups (public, amateur athletes, professional athletes and coaches, artificial pitch installers).

According to current knowledge, the results of the HRE show that the VOC and aldehyde emissions identified for the three types of artificial floors and for the reference control present no cause for concern as regards human health in an indoor situation, for the workers responsible for laying the floors or for the general public, professional or amateur athletes, whether adults or children, with the exception of the case of workers installing artificial surfaces in small and poorly ventilated gymnasia who are exposed for over 5 years (worst-case scenario). In this case, it is recommended, when the floors are installed, that a minimum air renewal rate of 2 vol.h^{-1} is assured.

This type of recommendation corresponds to that of the Observatoire français de la Qualité de l'Air Intérieur (OQAI), which recommends to private individuals several days' ventilation of rooms of a building which have just been constructed or renovated or after the installation of new furniture or decoration (page 5 of the "Les bons gestes pour un bon air" *(good moves for good air)* guide.

In conclusion to its study, the INERIS stipulates that the health risks associated with the inhalation of VOC and aldehydes emitted by artificial surfaces on pitches in outdoor situations present no actual cause for concern as regards human health.

Initiated in 2005, this study was conducted with the scientific aim of getting as close as possible to the pitch usage conditions (representativity of the pilots conducted, quantities of materials tested, choice of limit thresholds, evaluation of effects over a year) and based on approaches and experimental protocols recognised on a European scale. The results of the evaluation of the environmental impact on the water and of the health risk evaluation (gaseous emissions) on the population groups show:

- comparable behaviour irrespective of the type of filling granulate (virgin TPE and EPDM, used tyre granulates),
- an absence of impact of this type of work on water resources,
- no effect worthy of concern on the health associated with the inhalation of VOC and aldehydes emitted by artificial surfaces.

This data consequently provides vital information on the environmental and health effects linked to the use of elastomer granulates (virgin and from used tyres) as filling in 3rd-generation artificial turf. These results offer elements of response to the principal questions raised by the professionals and sports federations.

On a French and European scale, the results of these studies will be able to be used in order to confirm or develop tailored sampling protocols and laboratory tests permitting the innocuousness in terms of the environment and health of 3rd-generation artificial turf under usage conditions.

APPENDICES

Compound	CASE No.
VOC	
acetophenone	98-86-2
alpha-methylstyrene	98-83-9
aniline	62-53-3
benzene	71-43-2
benzothiazole	95-16-9
butan-1-ol	71-36-3
butylcyclohexane	1678-93-9
1,5,9-cyclododecatriene	4904-61-4
cyclohexane	110-82-7
cyclohexanone	108-94-1
cymene	99-87-6
decahydro-2-methylnaphtalene	?
decane	124-18-5
1,4-diacethylbenzene	1009-61-6
1,2-dichlorobenzene	95-50-1
diethylbenzene	135-01-3
1,2-dihydro-2,2,4-trimethylquinoline	147-47-7
diisopropenylbenzene	3748-13-8
diisopropylbenzene	99-62-7
2,4-diisopropyl-1,1-dimethylcyclohexane	?
dimethylcyclohexane	2207-01-4
dimethylcyclopentane	?
dimethylethylbenzene	98-06-6
dimethylethylcyclohexane	3178-22-1
dimethylhexene	?
dimethylpentanol	?
dimethylphenylmethanol	617-94-7
2,4-dimethylquinoline	1463-17-8
dimethyltrisulfide	3658-80-8
2,6-ditertbutyl-p-benzoquinone	?
2,6-ditertbutyl-4-methylphenol	?
dodecane	112-40-3
dodecene	25378-22-7
1,2-ethanediol	107-21-1
ethanone, 1-[4-(1-hydroxy-1-methylethylphenyl)]	?
ethylbenzene	100-41-4
ethylcyclohexane	1678-91-7
5-ethyldihydro-5-methyl-2(3H)-furanone	?
2-ethylhexanol	104-76-7
5-ethyl-2,2,3-trimethylheptane	?
ethyltoluene	622-96-8
2,2,3,5,5,6,6-heptamethyl-3-heptene	?
heptane	142-82-5
heptene	592-76-7
2,5-hexanedione	110-13-4
1-hydroxycumene	617-94-7
hydroxydiisopropylbenzene	4779-94-6
isobutene tetramere	115-11-7
1-isopropoxy-2-methyl-2-propanol	?
isopropenylacetophenone	?
isopropylacetophenone	?
Isopropylbenzene (or cumene)	98-82-6
isothiocyanato-cyclohexane	1122-82-3
1-methoxy-2-propanol	107-92-8
(1-methoxy-1-methylethyl)-benzene	?
methyldecane	6975-98-0

Compound	CASE No.
3-methylheptane	589-81-1
methyl-2-hexanone	?
methylcycloheptane	4126-78-7
methylcyclohexane	108-87-2
3-methylcyclohexen-1-one	?
methylcyclopentanol	1462-03-9
methylethylcyclohexane	1678-82-6
methylethylcyclopentane	?
methylisobutylcetone (MIBK)	108-10-1
2-methyl-2-(1-methylethoxy)-propane	?
methylpropylbenzene	99-87-6
4-methyl-pyridine	1333-41-1
naphthalene	91-20-3
octahydro naphthalene methanol	?
octane	111-65-9
octenone	4312-99-6
pentadecane	629-62-9
2,2,4,6,6-pentamethylheptane	13475-82-6
2,2,4,6,6-pentamethyl-3-heptene	123-48-8
phenol	108-95-2
4-phenylcyclohexene	4994-16-5
1,2-propanediol	57-55-6
propylbenzene	103-65-1
propylcyclohexane	1678-92-8
styrene	100-42-5
4-tert-butylacetophenone	?
4-tert-butylcyclohexanone	98-53-3
tert-butylformamide	2425-74-3
tetradecane	629-59-4
tetraisobutylene	15220-85-6
tetramethylcyclopentane	*isomers*
3,3,6,6-tetramethyl-1,4-cyclohexadiene	?
2,2,6,6-tetramethyleneheptane	?
trichloroethylene	79-01-6
tridecane	629-50-5
1,2,3-trimethylbenzene	526-73-8
1,2,4-trimethylbenzene	95-63-6
1,3,5-trimethylbenzene	108-67-8
trimethylcyclohexane	*isomers*
3,5,5-trimethyl-2-cyclohexen-1-one	78-59-1
trimethylcyclopentane	*isomers*
1,3,3-trimethyl-2-methylene-indoline	118-12-7
toluene	108-88-3
undecane	1120-21-4
xylenes	1330-20-7
acetaldehyde	75-07-0
benzaldehyde	100-52-7
butyraldehyde	123-72-8
crotonaldehyde	123-73-9
decanal	112-31-2
formaldehyde	50-00-0
hexaldehyde	66-25-1
nonanal	124-19-6
propionaldehyde	123-38-6
m/p-tolualdehyde	620-23-5
valeraldehyde (pentanal)	110-62-3

Table 5: List of substances studied (in bold: the 16 substances with a RTV)

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